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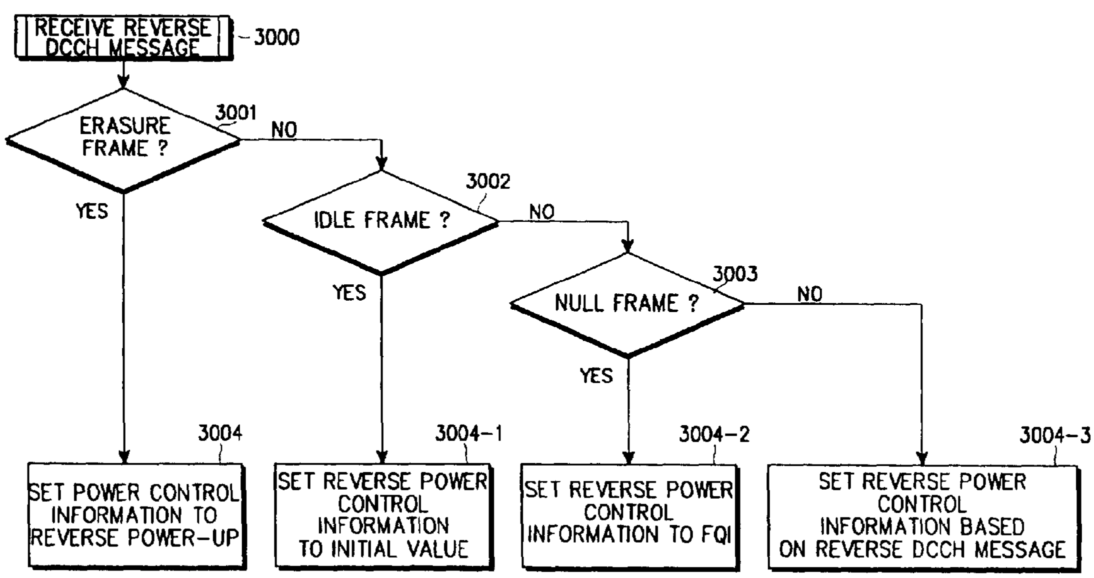
(54) Title: METHOD OF SUPPORTING POWER CONTROL ON DCCH IN BS



(57) Abstract: There is provided a method of transmitting power control information to a BSC (Base Station Controller) in a BTS (Base station Transceiver System) of a mobile communication system. The BTS receives forward power control (FPC) mode information indicating a low power control from the BSC and transmits the FPC mode information to an MS (Mobile Station). Then, the BTS extracts a QIB (Quality Indicator Bit) that is a power control command in a frame period from a reverse pilot channel received from the MS according to the FPC mode information and determines the status of the QIB. The BTS transmits information requesting the BSC to change a threshold for a power control on a forward DCCH (Dedicated Control Channel) based on the determined QIB status to the BSC.

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METHOD OF SUPPORTING POWER CONTROL ON DCCH IN BS

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates generally to a CDMA (Code Division Multiple Access) mobile communication system, and in particular, to an apparatus and method for supporting forward and reverse power control on a DCCH (Dedicated Control Channel) in a BTS (Base station Transceiver System) and a BSC (Base Station Controller).

2. Description of the Related Art

A discontinuous transmission (DTX) mode refers to a mode in which data is transmitted in frames only when transmission data is generated in a wired system or a mobile communication system. Data transmission in the DTX mode minimizes transmission power and increases the whole system capacity due to the decrease of interference with the system.

The DTX, however, exhibits a problem when a receiver does not know whether frames have been transmitted or not because a transmitter transmits frames irregularly. That makes it impossible for a BTS to perform a forward power control. More specifically, when a receiver in a mobile station (MS) cannot make a right judgment about data transmission, it does not rely on decoder decision parameters including CRC (Cyclic Redundancy Code) and decoding results. Hence, the transmission power of the MS cannot be controlled accurately by known methods suitable for a continuous transmission mode.

Both a DCCH and an SCH (Supplemental Channel) support the DTX mode. The DCCH is characterized by data transmission only when transmission data is generated in a higher layer, which makes the DCCH suitable as a control channel for efficient packet services. The DCCH is supposed to transmit null frames for power control during the DTX period. The SCH supports a DTX mode in which no data is transmitted in the absence of transmission data. The SCH transmits no frames during the DTX period.

FIG. 1 is a block diagram of a prior art mobile communication system. The mobile communication system is a reference model of 3G IOS (Interoperability Specifications) with an MSC (Mobile Switching Center), BSs (Base Stations), and a digital air interface between the BSs, which are well known.

Referring to FIG. 1, an interface A1 is defined for signaling and interfaces A2 and A5 (exclusively for circuit data) are defined for user traffic between an MSC 20 and a BSC 32. An interface A3 is defined to connect a target BS 40 to an SDU (Frame Selection /Distribution Unit Function) 34 of a source BS 30 to implement a soft/softer handoff.. Signaling messages and user data are transmitted between the target BS 40 and the SDU 34 of the source system 30 by the interface A3. An interface A7 is defined for signal transmission/reception between the target BS 40 and the source BS 30 for inter-BS soft/softer handoff.

The wired communication lines of this CDMA mobile communication system include a forward link directed from the MSC 20 to the BS 30, a reverse link directed from the BS 30 to the MSC 20, and a line between the BSs 30 and 40. The MSC 20 includes a call control and mobility management block 22 and a switching block 24. The MSC 20 is connected to a data network (not shown) such as the Internet through an IWF (InterWorking Function) 50. Interfaces A8 and A9 are defined for user traffic and signaling, respectively between a BS and a PCF (Packet Control Function) 60 and interfaces A10 and A11 are defined for user traffic and signaling, respectively, between the PCF 60 and a PDSN (Packet Data Serving Node) 70.

FIG. 2 is a diagram showing a DCCH signal flow between a BTS and a BSC (BSC-SDU) in conventional CDMA technology. This operation may occur between the BSC 32 (BSC-SDU 34) and a BTS 36 in the source BS 30, or a BSC 42 and a BTS 44 in the target BS 40.

With continued reference to FIG. 2, upon detection of a DTX mode, the BTS determines the type of a data frame to transmit to the BSC and generates a reverse DCCH message in step 11. The reverse DCCH message is supposed to be transmitted to the BSC in every predetermined period (e.g. 20ms) in response to a reverse DCCH frame received in the predetermined period from an MS (not

shown). Step 11 will be described later in more detail with reference to FIGS. 3A and 3B.

In step 12, the BTS transmits the reverse DCCH message to the BSC. The reverse DCCH message may contain a data/null/idle/erasure frame. The BSC receives and processes the reverse DCCH message and generates a forward DCCH message in step 13. Reception of the reverse DCCH message is described below in more detail with reference to FIG. 5; processing the reverse DCCH message and generation of the forward DCCH message is described below with reference to FIGS. 4A and 4B.

In step 14, the BSC transmits the forward DCCH message to the BTS. The forward DCCH message may contain a data/null/idle/erasure frame. The BTS performs a forward/reverse power control for the MS based on power control information included in the forward DCCH message in step 15. Reception of the forward DCCH message is described below in more detail with reference to FIG. 6.

To summarize the operation shown in FIG. 2, after receiving a data frame in every predetermined period (20ms) from the MS, the BTS generates a reverse DCCH message in the predetermined period and transmits it to the BSC. The BSC processes the reverse DCCH message, generates a forward DCCH message, and transmits it to the BTS. Then, the BTS performs a power control for the MS based on power control information included in the forward DCCH message.

FIGS. 3A and 3B are flowcharts illustrating a conventional reverse DCCH message transmitting operation. In this operation, the BTS transmits a frame received in the predetermined period from the MS as a reverse DCCH message to the BSC-SDU. The following description is conducted with the appreciation that a reverse DCCH message is constructed in the same format as an FCH (Fundamental Channel) message shown in FIGS. 7 and 10, and thus defined as a reverse FCH/DCCH message.

Referring to FIG. 3A, the BTS determines whether it has secured radio resources related with the MS and acquired the MS in step 101. If it has not, the BTS considers that it tries to synchronize with the MS and sets Frame Content in

an IS-2000 reverse DCCH message shown in FIG. 10 to an idle frame to synchronize with the BSC-SDU in step 104. Since the BTS is being synchronized with the BSC-SDU, it sets power control information in the reverse FCH/DCCH message that will be transmitted to the BSC-SDU to values negligible to the BSC-SDU in step 106. In step 107, the BTS transmits the IS-2000 reverse FCH/DCCH message to the BSC-SDU.

On the other hand, if the BTS has secured the radio resources related with the MS and acquired the MS in step 101, it checks the quality of a frame received from the MS in step 102. If the data frame is bad, the BTS sets Frame Content of the reverse FCH/DCCH message to an erasure frame in step 104-1. In step 106-1, the BTS sets the power control information of the reverse FCH/DCCH message to values negligible to the BSC-SDU. The BTS transmits the IS-2000 reverse FCH/DCCH message without any data to the BSC-SDU since the received frame is bad in step 107-1. Upon recognition of the erasure frame, the BSC-SDU requests the MS to increase its transmission power regarding reverse power control. That is, since the data frame received from the MS is bad, the BSC-SDU will request the MS to transmit a data frame with incremented power.

If the BTS determines that the received frame is good in step 102, it detects a DTX mode during reception of a reverse DCCH frame from the MS by a known DTX mode detection method applied to a radio transmission period between an MS and a BTS in step 103. If the DTX mode is detected, the BTS goes to step 104-3, otherwise, it goes to step 104-2.

In step 104-2, the BTS sets Frame Content of the reverse FCH/DCCH message to a data frame. The BTS checks whether Frame Content of the latest forward DCCH frame received from the BSC-SDU indicates a null frame in step 105A. If it does not indicate a null frame, the BTS sets information elements related with power control according to the DCCH frame received from the MS in step 106-2.

On the contrary, if the latest forward DCCH frame is a null frame, the BTS sets power control information in the reverse FCH/DCCH message to be negligible to the BSC-SDU in step 106-3. In step 107-2, the BTS transmits the IS-2000

reverse FCH/DCCH message with the data of the 20-ms data frame received from the MS encapsulated to the BSC-SDU. The data received from the MS is filled in Reverse Link Information of the reverse FCH/DCCH message.

Upon detection of a DTX mode in step 103, the BTS sets Frame Content of the reverse FCH/DCCH message to a null frame in step 104-3 in FIG. 3B. In step 105B, the BTS checks whether the latest forward DCCH message is a null frame. If it is not a null frame, the BTS maintains power control information at the DTX mode detected point in the power control information elements of the reverse FCH/DCCH message in step 106-4.

On the other hand, if the latest forward DCCH is a null frame, the BTS sets the power control information of the reverse FCH/DCCH message to be negligible to the BSC-SDU in step 106-5. Since there is no data in the 20-ms frame received from the MS, the BTS transmits the IS-2000 reverse FCH/DCCH message without any data to the BSC-SDU in step 107-3. Here, no data is filled in Reverse Link Information.

FIGS. 4A and 4B are flowcharts illustrating a conventional forward DCCH message transmitting operation. In this operation, the BSC-SDU transmits a forward DCCH message to the BTS in every predetermined period (20ms). It is to be noted in the following description that a forward DCCH message is constructed in the same format as an FCH shown in FIGS. 7 and 8, and thus defined as a forward FCH/DCCH messages.

Referring to FIG. 4A, the BSC-SDU determines whether it has secured forward radio resources related with the MS and acquired the MS in step 201. If it has not, the BSC-SDU considers that it is being synchronized with the MS and sets Frame Content in an IS-2000 forward FCH/DCCH message of FIG. 8 to an idle frame to synchronize with the BTS in step 203. Since the BSC-SDU is being synchronized with the BTS, it sets power control information in the forward FCH/DCCH message that will be transmitted to the BTS to appropriate values in step 206. Here, forward power control information is set to an initial value for control of the MS and reverse power control information is set based on power control information included in a reverse DCCH message received every 20ms

from the BTS. In step 207, the BSC-SDU transmits the forward DCCH message with the set power control information to the BTS. Here, no data is loaded in the forward DCCH message.

On the other hand, if the BSC-SDU has secured the radio resources related with the MS and acquired the MS in step 201, it checks whether there is data to be transmitted to the MS in the BSC or an external network element (e.g., PDSN) in step 202. If there is no data to transmit to the MS, the BSC-SDU goes to step 203-1 and if there exists data to transmit to the MS, it goes to step 203-2.

In step 203-1, the BSC-SDU sets Frame Content of the forward FCH/DCCH message to a null frame. The BSC-SDU checks whether Frame Content of the latest reverse DCCH frame received from the BTS indicates one of a null frame and an idle frame in step 204A. If it is neither a null frame nor an idle frame, the BSC-SDU checks whether Frame Content of the latest reverse DCCH message indicates an erasure frame in step 205A. If it does not indicate an erasure frame, the BSC-SDU sets power control information in the forward FCH/DCCH message based on power control information included in the reverse DCCH message received from the BTS every 20ms in step 206-1A. Since there is no data to transmit to the MS, the BSC-SDU loads no data in the forward FCH/DCCH message and transmits it to the BTS in step 207-1.

If Frame Content of the latest reverse DCCH message indicates an erasure frame in step 205A, the BSC-SDU sets a reverse power control information value to indicate power-up on a reverse link in the forward FCH/DCCH message in step 206-2A. Since there exists no data to transmit to the MS, the BSC-SDU transmits the forward FCH/DCCH frame without any data to the BTS in step 207-1.

If Frame Content of the latest reverse DCCH message indicates one of a null frame and an idle frame in step 204A, the BSC-SDU maintains the power control information included in the reverse DCCH message received from the BTS every 20ms. The power control information is maintained until an erasure frame or a data frame is received from the BTS. That is, the BSC-SDU sets the power control information value to the previous value in the forward FCH DCCH message in step 206-3A. Since there exists no data to transmit to the MS, the

BSC-SDU transmits the forward FCH/DCCH frame without any data to the BTS in step 207-1.

If there exists data to transmit to the MS in step 202, the BSC-SDU sets Frame Content of the forward FCH/DCCH to a data frame of 9600bps or 14400bps in step 203-2 of FIG. 4B. Then, steps 204B to 207-2 are performed in the same manner as steps 204A to 206-3A. In step 204B, the BSC-SDU checks whether Frame Content of the latest reverse DCCH message is one of a null frame and an idle frame. If it is neither a null frame nor an idle frame, the BSC-SDU checks whether Frame Content of the latest reverse DCCH message indicates an erasure frame in step 205B. If it does not indicate an erasure frame either, it sets the power control information in the forward DCCH message based on power control information included in the reverse DCCH message received from the BTS in step 206-1B. Since there is data to transmit to the MS, the BSC-SDU transmits the forward FCH/DCCH message with the data to the BTS in step 207-2.

If the Frame Content of the latest reverse DCCH message indicates an erasure frame in step 205B, the BSC-SDU sets the reverse power control information value to indicate power-up on the reverse link in the forward DCCH message in step 206-2B. Since there is data to transmit to the MS, the BSC-SDU transmits the forward FCH/DCCH frame with the data to the BTS in step 207-2.

If Frame Content of the latest reverse DCCH message indicates one of a null frame and an idle frame in step 204B, the BSC-SDU maintains the power control information included in the reverse DCCH message received from the BTS every 20ms. The power control information is maintained until an erasure frame or a data frame is received from the BTS. That is, the BSC-SDU sets the power control information of the forward DCCH message to the previous values in step 206-3B. Since there is data to transmit to the MS, the BSC-SDU transmits the forward FCH/DCCH frame with the data to the BTS in step 207-2.

FIG. 5 is a flowchart illustrating a conventional reverse DCCH message receiving operation. In this operation, the BSC-SDU receives and processes a reverse DCCH message in every predetermined period (e.g., 20ms) from the BTS.

Referring to FIG. 5, the BSC-SDU receives a reverse FCH/DCCH message from the BTS every 20ms in step 300. The BSC-SDU determines whether Frame Content of the received message indicates an erasure frame in step 301. If the received frame is an erasure frame, the BSC-SDU goes to step 304, otherwise, it goes to step 302. In the case of an erasure frame, it implies that a frame received at the BTS from the MS is bad. Therefore, the BSC-SDU neglects all information in the received reverse DCCH message and generates a forward FCH/DCCH message indicating reverse power-up in step 304.

If the received reverse DCCH frame is not an erasure frame in step 301, the BSC-SDU determines whether Frame Content of the received frame indicates an idle frame in step 302. In the case of an idle frame, the BSC-SDU neglects all information of the received reverse FCH/DCCH message and generates a forward FCH/DCCH message with reverse power control information maintained at an initial value, considering that the BTS has not recognized the radio resources related with the MS or has not assigned the radio resources in step 304-1.

If the received reverse FCH/DCCH message is not an idle frame in step 302, the BSC-SDU determines whether its Frame Content indicates a null frame in step 303. In the case of a null frame, the BSC-SDU neglects all information of the received reverse FCH/DCCH message and generates a forward DCCH message with reverse power control information maintained at a value set just before a DTX mode is recognized, considering that a reverse channel between the MS and the BTS is in the DTX mode in step 304-2.

If the reverse FCH/DCCH message is not a null frame in step 303, which implies that it is a data frame, the BSC-SDU transmits data included in Reverse Link Information of the reverse FCH/DCCH message to a corresponding data processing device (not shown) according to the type of the data and generates a forward DCCH message with forward/reverse power control information based on an analysis of power control information included in the reverse FCH/DCCH message in step 304-3.

FIG. 6 is a flowchart illustrating a conventional forward FCH/DCCH message receiving operation. In this operation, the BTS receives and processes a

forward FCH/DCCH message in every predetermined period (e.g., 20ms) from the BSC-SDU.

Referring to FIG. 6, the BTS receives a forward FCH/DCCH message from the BSC every 20ms in step 400. The BTS determines whether Frame Content of the received message indicates an idle frame in step 401. In the case of an idle frame, the BTS analyses all information of the received forward FCH/DCCH message and transmits reverse/forward power control information set in the forward message to a power control processor (not shown) in step 403. Here, no frames are transmitted on a forward radio link.

If the forward FCH/DCCH message is not an idle frame in step 401, the BTS determines whether Frame Content of the forward FCH/DCCH message indicates a null frame in step 402. In the case of a null frame, the BTS analyses all information of the forward FCH/forward DCCH message and transmits reverse/forward power control information set in the forward message to the power control processor in step 403-1. Here, no frames are transmitted on the forward radio link.

If the forward FCH/DCCH message is not a null frame in step 402, which implies that it is a data frame, the BTS analyses all information of the forward FCH/DCCH message and transmits reverse/forward power control information set in the forward message to the power control processor in step 403-2. Here, data included in the channel information of the forward DCCH message is transmitted on the forward radio link.

FIG. 7 illustrates the structure of a message transmitted from the BSC to the BTS on a user traffic sub-channel of an FCH. The message is used to transmit a forward traffic channel frame directed to the MS. This message can be transmitted between a BTS and a BSC in the same BS or between a BTS and a BSC in different BSs although the message is differently called according to the interfaces. For example, the message is called a forward Abis DCCH message in the former case and a forward A3 DCCH message in the latter case.

FIG. 8 illustrates an example Forward Layer 3 FCH/DCCH Data

representing control information for a forward CDMA traffic channel frame and a packet directed from an SDU to a target BTS.

FIG. 9 illustrates a message transmitted from the BTS to the BSC on a user traffic sub-channel of an FCH. This message is used for the BTS to transmit a reverse traffic channel frame and control information. The message can be transmitted between a BTS and a BSC in the same BS or between a BTS and a BSC in different BSs although the message is differently called according to the interfaces. For example, the message is called a reverse Abis DCCH message in the former case and a reverse A3 DCCH message in the latter case.

FIG. 10 illustrates an example Reverse Layer 3 FCH/DCCH Data representing control information for a reverse CDMA traffic channel frame and a packet directed from a target BTS to an SDU.

The above-described conventional method produces the following two main disadvantages in a BS.

1. Unstable forward/reverse power control for a DTX period: Since power control information effective at the start point of a DTX mode is maintained for the whole DTX period, an effective power control cannot be performed in reality for the DTX period. Furthermore, power control information for use in power control at the end of the DTX mode reflects no real radio situations, which increases an error rate for a radio transmission period; and

2. Non-supportability for slow power control on forward DCCH: One bit for slow power control, namely an EIB (Erasure Indicator Bit) for an FCH is transmitted in every 20-ms frame in the conventional technology. Because a DCCH supports a DTX mode, the EIB for the FCH is not effective in slow power control. Therefore, slow forward power control should be performed on the DCCH by supporting a QIB (Quality Indicator Bit) that works well in both a DTX mode and a non-DTX mode. Here, the EIB is one bit of power control information for an FCH in a 20-ms frame and the QIB is one bit of power control information for a DCCH in a 20-ms frame.

SUMMARY OF THE INVENTION

It is, therefore, an object of the present invention to provide an apparatus and method for effectively supporting power control on a forward/reverse DCCH for a DTX period in a CDMA mobile communication system.

It is another object of the present invention to provide an apparatus and method for performing slow power control on a DCCH by use of a QIB in a CDMA mobile communication system.

The foregoing and other objects are achieved by a method of supporting power control on a DCCH in a BS. According to one aspect of the present invention, a BTS receives forward power control (FPC) mode information indicating a low power control from the BSC and transmits the FPC mode information to an MS. Then, the BTS extracts a QIB that is a power control command in a frame period from a reverse pilot channel received from the MS according to the FPC mode information and determines the status of the QIB. The BTS transmits information requesting the BSC to change a threshold for a power control on a forward DCCH based on the determined QIB status to the BSC.

According to another aspect of the present invention, a BTS detects a DTX period by measuring the energy of a DCCH data frame received from an MS, determines reception status by measuring the energy of a PCB on a reverse pilot channel if the DTX mode is detected, determines FQI (Frame Quality Indicator) information according to the determined reception status, and transmits the FQI information to a BSC.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other objects, features and advantages of the present invention will become more apparent from the following detailed description when taken in conjunction with the accompanying drawings in which:

FIG. 1 illustrates a 3G IOS reference model of an MSC, BSs, and digital air interfaces between the BSs in a prior art mobile communication system;

FIG. 2 is a diagram illustrating a conventional DCCH signal exchange

between a BTS and a BSC;

FIGS. 3A and 3B are flowcharts illustrating a prior art reverse DCCH message transmission procedure in which the BTS transmits a frame received from an MS in every predetermined period as a reverse DCCH message to the BSC-SDU;

FIGS. 4A and 4B are flowcharts illustrating a prior art forward DCCH message transmission procedure in which the BSC-SDU transmits a forward DCCH message to the BTS in every predetermined period;

FIG. 5 is a flowchart illustrating a prior art reverse DCCH message reception procedure in which the BSC-SDU receives and processes a reverse DCCH message from the BTS in the predetermined period;

FIG. 6 is a flowchart illustrating a prior art forward DCCH message reception procedure in which the BTS receives and processes the forward DCCH message from the BSC-SDU in the predetermined period;

FIG. 7 illustrates a forward DCCH data frame directed from the BSC to the BTS in the prior art mobile communication system;

FIG. 8 illustrates the structure of the forward DCCH data frame directed form the BSC to the BTS in the prior art mobile communication system;

FIG. 9 illustrates a reverse DCCH data frame directed from the BTS to the BSC in the prior art mobile communication system;

FIG. 10 illustrates the structure of the reverse DCCH data frame directed form the BTS to the BSC in the prior art mobile communication system;

FIGS. 11A and 11B are flowcharts illustrating a reverse DCCH message transmission procedure according to the present invention, wherein the BTS transmits a frame received in every predetermined period from the MS as a reverse DCCH message to the BSC-SDU;

FIG. 12 illustrates a reverse DCCH data frame directed from the BTS to the BSC according to the present invention;

FIG. 13 illustrates the structure of the reverse DCCH data frame directed from the BTS to the BSC according to the present invention;

FIGS. 14A and 14B are flowcharts illustrating a forward DCCH message transmission procedure according to the present invention in which the BSC-SDU transmits a forward DCCH message to the BST in every predetermined period;

FIG. 15 is a flowchart illustrating a reverse DCCH message reception procedure according to the present invention in which the BSC-SDU receives and

processes a reverse DCCH message from the BST in the predetermined period;

FIG. 16 is a flowchart illustrating a forward DCCH message reception procedure according to the present invention in which the BTS receives and processes the forward DCCH message from the BSC-SDU in the predetermined period;

FIGS. 17A and 17B are flowcharts illustrating an operation of setting QIB/EIB for slow forward power control based on QIB/EIB of a reverse pilot channel in the BTS according to the present invention;

FIG. 18 is a flowchart illustrating a control operation for checking the CRC/signaling quality of a reverse frame according to the present invention;

FIG. 19 is a flowchart illustrating an embodiment of an operation of determining a FQI by means of a reverse pilot channel according to the present invention; and

FIG. 20 is a flowchart illustrating another embodiment of the operation of determining a FQI by means of a reverse pilot channel according to the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Preferred embodiments of the present invention will be described hereinbelow with reference to the accompanying drawings. In the following description, well-known functions or constructions are not described in detail since they would obscure the invention in unnecessary detail.

The present invention provides a method of supporting a radio channel environment in which a large amount of data is processed in a BTS and a BSC of a CDMA mobile communication system. Particularly, the present invention provides a method of supporting forward/reverse power control on a DCCH that is used for transmission of high rate data and related signals, power control, and MAC transmission in a BTS and a BSC.

FIGS. 11A and 11B are flowcharts illustrating a reverse DCCH message transmission procedure according to the present invention, wherein the BTS transmits a frame received in every predetermined period from the MS as a reverse DCCH message to the BSC-SDU

Referring to FIG. 11A, the BTS determines whether it has secured radio resources related with the MS and acquired the MS in step 1001. If it has not, the BTS considers that it is being synchronized with the MS and sets Frame Content in an IS-2000 reverse FCH/DCCH message shown in FIG. 13 to an idle frame to synchronize with the BSC-SDU in step 1004. Since the BTS is being synchronized with the BSC-SDU, it sets power control information of the reverse FCH/DCCH message that will be transmitted to the BSC-SDU to values negligible to the BSC-SDU in step 1006. In step 1007, the BTS transmits the IS-2000 reverse FCH/DCCH message to the BSC-SDU.

On the other hand, if the BTS has secured the radio resources related with the MS and acquired the MS in step 1001, it checks the quality of a frame received from the MS in step 1002. If the data frame is bad, the BTS sets Frame Content in the reverse FCH/DCCH message to an erasure frame in step 1004-1. In step 1006-1, the BTS sets the power control information of the reverse FCH/DCCH message to values negligible to the BSC-SDU. Since the received frame is bad, the BTS transmits the IS-2000 reverse FCH/DCCH message without any data to the BSC-SDU in step 1007-1. Upon recognition of the erasure frame, the BSC-SDU will request the MS to transmit a frame with incremented power since the frame received from the MS is bad.

If the BTS determines that the received data frame is good in step 1002, it detects a DTX mode during receiving a reverse DCCH frame from the MS by a known DTX mode detection method applied to a radio period between an MS and a BTS in step 1003. If the DTX mode is detected, the BTS goes to step 1004-3 and otherwise, it goes to step 1004-2.

In step 1004-2, the BTS sets Frame Content of the reverse FCH/DCCH message to a data frame. The BTS checks whether the latest forward DCCH frame received from the BSC-SDU is a null frame in step 1005A. If it is not a null frame, the BTS extracts power control information (PCB or QIB) from a reverse pilot channel according to a predetermined forward power control mode (FPC_MODE) in step 1006-2. If a fast power control mode is set, the BTS extracts a PCB from the reverse pilot channel at 800, 400, or 200bps according to

FPC_MODE=000, 001, 010, or 110, performs a fast inner loop forward power control, and sets QIB/EIB of the reverse FCH/DCCH message to 0. On the other hand, if a slow power control mode is set, the BTS extracts a QIB from the reverse pilot channel received from the MS according to FPC_MODE=100 or 101, performs a slow power control, and sets QIB/EIB of the reverse FCH/DCCH message to the extracted QIB value (see FIG. 13).

If the latest forward DCCH message is a null frame, which implies that the previous forward DCCH frame was transmitted to the MS in the DTX mode, the MS generates a power control command with the null frame received from the BTS and transmits the power control command on a reverse pilot channel. Here, the MS transmits a PCB or QIB to the BTS according to a preset forward power control mode. Thus, the BTS extracts the power control information (PCB or QIB) from the reverse pilot channel according to FPC_MODE in step 1006-3. If a fast power control mode is set, i.e., the PCB is received, the BTS extracts a PCB from the reverse pilot channel at 800, 400, or 200bps according to FPC_MODE=000, 001, 010,1 or 10; performs a fast inner loop forward power control; and sets QIB/EIB of the reverse FCH/DCCH message to 0.

On the other hand, if a slow power control mode is set, i.e., the QIB is received, the BTS extracts a QIB from the reverse pilot channel according to FPC_MODE=100 or 101; performs a slow power control; and sets QIB/EIB of the reverse FCH/DCCH message to the extracted QIB value (see FIG. 13). In step 1007-2, the BTS transmits the IS-2000 reverse FCH/DCCH frame with the data of the 20-ms frame received from the MS encapsulated to the BSC-SDU.

If the DTX mode is detected in step 1003, the BTS sets Frame Content of the reverse FCH/DCCH message to a null frame in step 1004-3 of FIG. 11B. In step 1005B, the BTS checks whether the latest forward DCCH message received from the BSC-SDU is a null frame. If it is not a null frame, the BTS extracts power control information (PCB or QIB) from the reverse pilot channel received from the MS according to FPC_MODE in step 1006-4.

In the case of a PCB, the BTS performs a fast inner loop forward power control at 800, 400, or 200bps according to FPC_MODE=000, 001, 010, or 110

and sets QIB/EIB of the reverse FCH/DCCH message to 0. On the other hand, in the case of a QIB, the BTS performs a slow power control according to FPC_MODE=100 or 101 and sets QIB/EIB of the reverse FCH/DCCH message to the QIB of the reverse pilot channel.

An information element related with power control in the reverse DCCH message directed to the BSC-SDU, FQI is set to 0 or 1 according to an inner FQI decision algorithm (see FIGs. 19 and 20) of the BTS in order to indicate that the reverse 20-ms frame is bad or good. The other power control information values are set to appropriate values. However, if the latest forward DCCH message is a null frame, this implies that the previous DCCH frame was transmitted to the MS in the DTX mode. Therefore, the MS generates a power control command based on the null frame received from the BS and transmits it on a reverse pilot channel. Here, the MS transmits a PCB or a QIB to the BS according to a preset forward power control mode. Thus, the BTS extracts the power control information (PCB or QIB) from the reverse pilot channel according to FPC_MODE in step 1006-5.

In the case of a PCB, the BTS performs a fast inner loop forward power control at 800, 400, or 200bps according to FPC_MODE=000, 001, 010, or 110 and sets QIB/EIB of the reverse FCH/DCCH message to 0. On the other hand, in the case of a QIB, the BTS performs a slow power control according to FPC_MODE=100 or 101 and sets QIB/EIB of the reverse FCH/DCCH message to the QIB of the reverse pilot channel. FQI is set to 0 or 1 according to an inner FQI decision algorithm of the BTS in order to indicate that the reverse 20-ms frame is bad or good. The other power control information values are set to appropriate values. Since there is no data in the 20-ms frame received from the MS, the BTS transmits the IS-2000 reverse FCH/DCCH frame without any data to the BSC-SDU. Reverse Link Information in the frame has no data.

FIGS. 14A and 14B are flowcharts illustrating a forward DCCH message transmitting operation according to the present invention. In this operation, the BSC-SDU transmits a forward DCCH message to the BTS in every predetermined period (20ms).

Referring to FIG. 14A, the BSC-SDU determines whether it has secured

forward radio resources related with the MS and acquired the MS in step 2001. If it has not, the BSC-SDU considers that it is being synchronized with the MS and sets Frame Content of an IS-2000 forward FCH/DCCH message to an idle frame to synchronize with the BTS in step 2003. Since the BSC-SDU is being synchronized with the BTS, it sets power control information of the forward FCH/DCCH message to appropriate values in step 2006. Here, forward power control (FPC) information can be set to an initial value for control of the MS and reverse power control (RPC) information is set based on power control information included in a reverse DCCH message received from the BTS every 20ms. In step 2007, the BSC-SDU transmits the forward DCCH message with the set power control information to the BTS. Here, no data is loaded in the forward DCCH message.

On the other hand, if the BSC-SDU has secured the radio resources related with the MS and acquired the MS in step 2001, it checks whether there is data to be transmitted to the MS in the BSC or an external network element (e.g., PDSN) in step 2002. If there is no data to transmit to the MS, the BSC-SDU goes to step 2003-1 and if there exists data to transmit to the MS, it goes to step 2003-2 of FIG. 14B.

In step 2003-1, the BSC-SDU sets Frame Content of the forward FCH/DCCH message to a null frame. The BSC-SDU checks whether Frame Content of the latest reverse DCCH frame received from the BTS indicates one of a null frame and an idle frame in step 2004A. If it is neither a null frame nor an idle frame, the BSC-SDU checks whether Frame Content of the latest reverse DCCH message indicates an erasure frame in step 2005A. If it does not indicate an erasure frame either, the BSC-SDU sets power control information in the forward FCH/DCCH message shown in FIG. 8 based on power control information included in the reverse DCCH message received from the BTS every 20ms in step 2006-1A. Since there is no data to transmit to the MS, the BSC-SDU loads no data in the forward FCH/DCCH message and transmits it to the BTS in step 2007-1.

If the Frame Content of the latest reverse DCCH message indicates an erasure frame in step 2005A, the BSC-SDU sets reverse power control information

to indicate power-up on the reverse link in the forward FCH/DCCH message in step 2006-2A. The erasure frame indicates that the frame received from the MS is bad. Since there exists no data to transmit to the MS, the BSC-SDU transmits the forward FCH/DCCH frame without any data to the BTS in step 2007-1.

If Frame Content of the latest reverse DCCH message indicates a null frame in step 2004A, the BSC-SDU refers to power control information (FQI, Reverse Link Quality, QIB, and FPC:SNR) included in the reverse DCCH message received from the BTS every 20ms in step 2006-3A. Since the reverse DCCH is in a DTX mode, the BSC-SDU also sets a threshold for an outer/inner loop power control on the reverse link and a set point for a slow power control on the forward link for the DTX period in corresponding fields of the forward FCH/DCCH message.

In the case of an idle frame in step 2004A, the BSC-SDU refers to the power control information (FQI, Reverse Link Quality, QIB, and FPC:SNR) included in the IS-2000 reverse DCCH message received from the BTS every 20ms in step 2006-3A. Since the idle frame indicates that the BTS is being synchronized with the MS, the BSC-SDU also sets an initial value for a power control on the reverse link and a set point for a slow power control on the forward link in the forward FCH/DCCH message (see FIG. 8).

If there exists data to transmit to the MS in step 2002, the BSC-SDU sets Frame Content of the forward FCH/DCCH message to a data frame in step 2003-2 of FIG. 14B. Then, steps 2004B to 2007-2 are performed in the same manner as steps 2004A to 2006-3A. In step 2004B, the BSC-SDU checks whether Frame Content of the latest reverse DCCH message is one of a null frame and an idle frame.

If it is neither a null frame nor an idle frame, the BSC-SDU checks whether Frame Content of the latest reverse DCCH message indicates an erasure frame in step 2005B. If it does not indicate an erasure frame either, the BSC-SDU sets power control information in the forward FCH/DCCH message shown in FIG. 8 based on the power control information (FQI, Reverse Link Quality, QIB, and FPC:SNR) included in the reverse DCCH message received from the BTS

every 20ms in step 2006-1B. Since there exists data to transmit to the MS, the BSC-SDU transmits the forward FCH/DCCH message with the data capsulated to the BTS in step 2007-2.

If the Frame Content of the latest reverse DCCH message indicates an erasure frame in step 2005B, the BSC-SDU sets reverse power control information to indicate power-up on a reverse link in the forward FCH/DCCH message in step 2006-2B. Since there exists data to transmit to the MS, the BSC-SDU transmits the forward FCH/DCCH frame with the data to the BTS in step 2007-2.

If a frame previously received from the BTS is a null frame in step 2004B, the BSC-SDU refers to power control information (FQI, Reverse Link Quality, QIB, and FPC:SNR) included in the IS-2000 reverse DCCH message received from the BTS every 20ms in step 2006-3B. Since the reverse DCCH is in a DTX mode, the BSC-SDU also sets a threshold for an outer/inner loop power control on the reverse link and a set point for a slow power control on the forward link for the DTX period in corresponding fields of the forward FCH/DCCH message.

In the case of an idle frame in step 2004B, the BSC-SDU refers to the power control information (FQI, Reverse Link Quality, QIB, and FPC:SNR) included in the IS-2000 reverse DCCH message received from the BTS every 20ms in step 2006-3A. Since the idle frame indicates that the BTS is being synchronized with the MS, the BSC-SDU also sets an initial value for a power control on the reverse link and a set point for a slow power control on the forward link in the forward FCH/DCCH message (see FIG. 8). Since there exists data to transmit to the MS, the BSC-SDU transmits the forward FCH/DCCH frame with the data to the BTS in step 2007-2.

FIG. 15 is a flowchart illustrating a reverse DCCH message receiving operation according to the present invention. In this operation, the BSC-SDU receives and processes a reverse DCCH message received in every predetermined period (e.g., 20ms) from the BTS.

Referring to FIG. 15, the BSC-SDU receives a reverse DCCH message from the BTS every 20ms in step 3000. The BSC-SDU determines whether

Frame Content of the received message indicates an erasure frame in step 3001. If the received frame is an erasure frame, the BSC-SDU goes to step 3004 and otherwise, it goes to step 3002. In the case of an erasure frame, it implies that a frame received at the BTS from the MS is bad. Therefore, the BSC-SDU neglects all information in the received reverse FCH/DCCH message and generates a forward FCH/DCCH message indicating reverse power-up in step 3004.

If the received reverse DCCH frame is not an erasure frame in step 3001, the BSC-SDU determines whether Frame Content of the received frame indicates an idle frame in step 3002. In the case of an idle frame, the BSC-SDU neglects all information of the received reverse FCH/DCCH message and generates a forward FCH/DCCH message with reverse power control information maintained at an initial value, considering that the BTS has not recognized the radio resources related with the MS or has not assigned the radio resources in step 3004-1.

If the received frame is not an idle frame in step 3002, the BSC-SDU determines that a reverse channel between the MS and the BTS is in the DTX mode and sets an outer loop threshold that is a set point for a PCB referring to FQI of the reverse IS-2000 DCCH message in step 3004-2. The BSC-SDU also checks whether the previous forward DCCH frame has errors by reading QIB from the reverse FCH/DCCH message, determines a gain ratio for forward power control, and writes the gain ratio in a corresponding field of the forward FCH/DCCH message.

If the received frame is not a null frame in step 3003, which implies that it is a data frame, the BSC-SDU transmits data included in Reverse Link Information of the received reverse FCH/DCCH message to a corresponding data processing device (not shown) according to the type of the data and generates the forward DCCH message with forward/reverse power control information set based on an analysis of power control information included in the reverse DCCH message in step 3004-3.

FIG. 16 is a flowchart illustrating a forward DCCH message receiving operation according to the present invention. In this operation, the BTS receives

and processes a forward DCCH message in every predetermined period (e.g., 20ms) from the BSC-SDU.

Referring to FIG. 16, the BTS receives a forward FCH/DCCH message from the BSC every 20ms in step 4000. The BTS determines whether Frame Content of the received message indicates an idle frame in step 4001. In the case of an idle frame, the BTS analyses all information of the received forward DCCH message and transmits reverse/forward power control information set in the forward message to a power control processor (not shown) in step 4003. Here, no frames are transmitted on a forward radio link.

If the received frame is not an idle frame in step 4001, the BTS determines whether Frame Content of the received frame indicates a null frame in step 4002. In the case of a null frame, the BTS analyses all information of the received forward DCCH message and transmits reverse/forward power control information set in the forward message to the power control processor in step 4003-1. Since the DTX mode is set, a forward slow power control set point is transmitted in the form of a QIB to the power control processor of the BTS as in a Non-DTX mode. Meanwhile, a DCCH null frame with a PCB is transmitted on the forward radio link.

If the received frame is not a null frame in step 4002, which implies that it is a data frame, the BTS analyses all information of the received forward DCCH message and transmits reverse/forward power control information set in the forward message to the power control processor in step 4003-2. That is, the BTS determines the reverse/forward power control information set in the forward message to be reverse/forward power control information for the MS in step 4003-2. Here, data included in Reverse Link Information of the forward DCCH message is transmitted on the forward radio link.

FIGS. 17A and 17B are flowcharts illustrating an operation of processing QIB/EIB of a reverse pilot channel frame received from the MS for slow forward power control on a DCCH according to the present invention. The slow power control is applied, for example, to a DTX period in which a null frame without any real data is received from the MS.

Referring to FIGS. 17A and 17B, the BTS receives a signal indicating the action time of FPC_MODE from the BSC in step 5000 and determines whether FPC_MODE is 011 from the forward DCCH message shown in FIG. 8 in step 5001. If FPC_MODE is 011, the BTS checks the QIB status of the reverse pilot channel every 1.25ms and determines a final QIB/EIB status of the reverse DCCH message as 0 or 1 in step 5004. If the QIB status is 1, the BTS sets QIB/EIB of a reverse DCCH message directed to the BSC-SDU to 1 in step 5005, and if the QIB status is 0, it sets QIB/EIB of the reverse DCCH message to 0 in step 5005-1.

If FPC_MODE is not 011 in step 5001, the BTS determines whether FPC_MODE is 100 in step 5002. If FPC_MODE is 100, the BTS checks the QIB status of the reverse pilot channel every 1.25ms and determines a final QIB status as 0 or 1 in step 5004-1. If the QIB status is 1, the BTS sets QIB/EIB of the reverse DCCH message directed to the BSC-SDU to 1 in step 5005-2 and if the QIB status is 0, it sets QIB/EIB of the reverse DCCH message, being transmitted to BSC-SDU, to 0 in step 5005-3.

If FPC_MODE is not 100 in step 5002, the BTS determines whether FPC_MODE is 101 in step 5003 of FIG. 17B. If FPC_MODE is 101, the BTS checks the QIB status of the reverse pilot channel every 1.25ms and determines a final QIB status as 0 or 1 in step 5004-2. If the QIB status is 1, the BTS sets QIB/EIB of the reverse DCCH message directed to the BSC-SDU to 1 in step 5005-4 and if the QIB status is 0, it sets QIB/EIB of the reverse DCCH message to 0 in step 5005-5. If FPC_MODE is not 101 in step 5003, the BTS sets QIB/EIB of the reverse DCCH message to 0 in step 5005-6.

FIG. 18 is a flowchart illustrating an FQI algorithm in which the quality of a reverse frame (CRC/signaling quality) is checked according to an embodiment of the present invention. Referring to FIG. 18, the BTS checks the energy of every reverse data frame received from the MS in step 6000 and determines whether a DTX mode has been set based on the energy in step 6001. In the case of a non-DTX mode, the BTS sets Frame Content of a reverse FCH/DCCH message to a data frame in step 6002. In step 6003, the BTS performs a CRC check on the data frame, and in step 6004, it determines whether the data frame is good based

on the CRC check. If the data frame is good, the BTS sets FQI of the reverse FCH/DCCH message to 1 in step 6005. If the data frame is bad, the BTS sets FQI of the reverse FCH/DCCH message to 0 in step 6005-1.

In the case of a DTX mode, the BTS sets Frame Content of the reverse FCH/DCCH message to a null frame in step 6002-1 and checks the PCB energy of the reverse pilot channel in step 6003-1 (see FIGS. 19 and 20). In step 6004-1, the BTS determines whether the received frame is good based on the PCB energy. If the frame is good, the BTS sets the FQI to 1 in step 6005-2, and if it is bad, the BTS sets the FQI to 0 in step 6005-3.

FIGS. 19 and 20 are flowcharts illustrating an FQI determination procedure. According to the FIG.s, PCB energy in steps 6003-1, 6004-1, 6005-2 and 6005-3 of FIG. 18 is checked and then, FQI bit is determined. Here, FIG 19 shows an example using a look-up table and FIG. 20 shows another example using a predetermined threshold, respectively according to an embodiment of the present invention.

Referring to FIG. 19, the BTS calculates an average energy Eb/Nt for a 20-ms period by measuring the energy of N PCGs (up to 16 PCGs) in a reverse pilot channel in step 7000. In step 7001, the BTS reads an FER (Frame Error Rate) corresponding to the average Eb/Nt from an Eb/Nt vs FER look-up table. This look-up table is derived from an AWGN performance curve according to preset offset values.

The BTS determines whether frame errors exist or not according to probability in step 7002. That is, the FER read from the table is compared with a random number between 0 and 1 generated with respect to an error rate corresponding to a given FER. If the random number is less than the FER, it is considered that the frame is bad and if the random number is greater than the FER, it is considered that the frame is good. The random number is a general algorithm that allows selecting an arbitrary number between 0 and 1, and for example, a pseudo random number generator may be corresponded. If the frame is good, the BTS sets FQI of the reverse FCH/DCCH message to 1 (good) in step 7003 and if the frame is bad, the BTS sets FQI of the reverse FCH/DCCH message to 0 (good)

in step 7003-1.

Referring to FIG. 20, the BTS calculates an average energy Eb/Nt for a 20-ms period by measuring the energy of N PCGs (up to 16 PCGs) in a reverse pilot channel in step 8000. In step 8001, the BTS compares the average Eb/Nt with a given threshold Eb/Nt that satisfies an FER 0.5. The threshold is obtained from an AWGN performance curve according to a preset offset value. The BTS determines whether frame errors exist or not according to the comparison result in step 8002.

That is, if the calculated Eb/Nt is less than the threshold, it is considered that the frame is bad and if the calculated Eb/Nt is greater than the threshold, it is considered that the frame is good. If the frame is good, the BTS sets FQI of the IS-2000 reverse FCH/DCCH message to 1 (good) in step 7003 and if the frame is bad, the BTS sets FQI of the IS-2000 reverse FCH/DCCH message to 0 (good) in step 8003-1.

As described above, the present invention is intended to implement a power control (slow power control) on a DCCH for a DTX period as is done for a non-DTX period. Therefore, the above description is about how to modify the conventional power control for the DTX period and how to utilize an FQI and a QIB for real-time power control for the DTX period.

Table 1 lists transmission rates versus FPC modes. Here, a slow power control is performed at a data rate of 50bps and a fast power control, at a data rate higher than 50bps. The slow forward power control is performed when FPC_MODE is 011, 100, or 101 according to the present invention. If this slow forward power control mode is set, an MS transmits a QIB on a reverse pilot channel and a BS (a BTS and a BSC) determines a threshold for the forward power control based on the QIB.

Table 1. Transmission rates versus FPC modes.

FPC_MODE	Primary (FCH, DCCH) power control	Secondary (SCH) power control
000	800bps	Not supported
001	400bps	400bps
010	200bps	600bps

011	50bps	Not supported
100	50bps	Not supported
101	50bps	50bps
110	400bps	50bps

In accordance with the present invention as described above, forward/reverse power control on a DCCH is supported for a DTX period with the same effect as for a non-DTX period. Therefore, power control is effectively performed.

While the invention has been shown and described with reference to certain preferred embodiments thereof, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the spirit and scope of the invention as defined by the appended claims.

WHAT IS CLAIMED IS:

1. A method of transmitting power control information to a BSC (Base Station Controller) in a BTS (Base station Transceiver System) of a mobile communication system, comprising the steps of:

receiving forward power control (FPC) mode information indicating a low power control from the BSC and transmitting the FPC mode information to an MS (Mobile Station);

extracting a QIB (Quality Indicator Bit) that is a power control command from a reverse pilot channel received from the MS according to the FPC mode information;

determining the status of the QIB; and

transmitting information requesting the BSC to change a threshold for a power control on a forward DCCH (Dedicated Control Channel) based on the determined QIB status to the BSC.

2. The method of claim 1, further comprising the steps of:

receiving FPC mode information indicating a fast power control from the BSC and transmitting the FPC mode information to the MS;

extracting a PCB (Power Control Bit) in every predetermined period from the reverse pilot channel received from the MS according to the FPC mode information; and

performing a fast forward power control according to the extracted PCB.

3. A method of transmitting power control information to a BSC in a BTS of a mobile communication system, comprising the steps of:

detecting a DTX (Discontinuous Transmission) period by measuring the energy of a DCCH frame received from an MS;

determining reception status by measuring the energy of a PCB on a reverse pilot channel if the DTX is detected;

determining FQI (Frame Quality Indicator) information according to the determined reception status; and

transmitting the FQI information to the BSC.

4. The method of claim 3, wherein the step of determining reception

status comprises the steps of:

comparing the measured energy with a predetermined threshold;

determining that the reception status is good if the energy is greater than the threshold; and

determining that the reception status is bad if the energy is less than the threshold.

5. The method of claim 3, wherein the step of determining reception status comprises the steps of:

determining an FER (Frame Error Rate) corresponding to the measured energy;

generating a random number in a predetermined range;

determining that the reception status is good if the random number is greater than the FER; and

determining that the reception status is bad if the random number is less than the FER.

6. A method of transmitting power control information to a BTS in a BSC of a mobile communication system, comprising the steps of:

checking FQI information in the latest reverse DCCH message received from the BSC if the frame content of the reverse message indicates a null frame;

determining a reverse link power control threshold based on the FQI information; and

transmitting a forward DCCH message with the threshold to the BTS.

7. The method of claim 6, further comprising the step of setting power control information requesting the MS to increase transmission power in the forward DCCH message and transmitting the forward DCCH message to the BTS if the frame content of the reverse message indicates an erasure frame.

8. The method of claim 6, further comprising the step of setting the power control information of the reverse message in the forward DCCH message and transmitting the forward DCCH message to the BTS if the frame content of the reverse message indicates a data frame.

9. The method of claim 6, further comprising the step of setting an initial value for the reverse link power control in the forward DCCH message and transmitting the forward DCCH message to the BTS if the frame content of the reverse message indicates an idle frame.

10. The method of claim 6, further comprising the step of setting information for a slow forward power control in the forward DCCH message and transmitting the forward DCCH message to the BTS if the frame content of the forward DCCH message indicates a null frame.

11. A method of transmitting power control information to a BTS in a BSC of a mobile communication system, comprising the steps of:

receiving a reverse DCCH message from the BTS;

extracting QIB information from the reverse DCCH message;

determining a threshold for a slow forward power control based on the QIB information; and

transmitting a forward DCCH message including the slow forward power control threshold to the BTS.

12. A method of transmitting power control information to a BSC in a BTS of a mobile communication system, comprising the steps of:

receiving FPC mode information indicating a slow power control from the BSC and transmitting the FPC mode information to an MS; and

extracting a QIB that is a power control command in a frame period from a reverse pilot channel received from the MS according to the FPC mode information and transmitting the QIB to the BSC.

13. The method of claim 12, further comprising the step of receiving a threshold for a forward power control that is determined based on the QIB from the BSC.

14. A method of transmitting power control information to a BSC in a BTS of a mobile communication system, comprising the steps of:

extracting power control information from a radio frame received from an

MS according to a set FPC mode;

performing a fast power control if the extracted power control information is a PCB and resetting a predetermined first field in a reverse DCCH message;

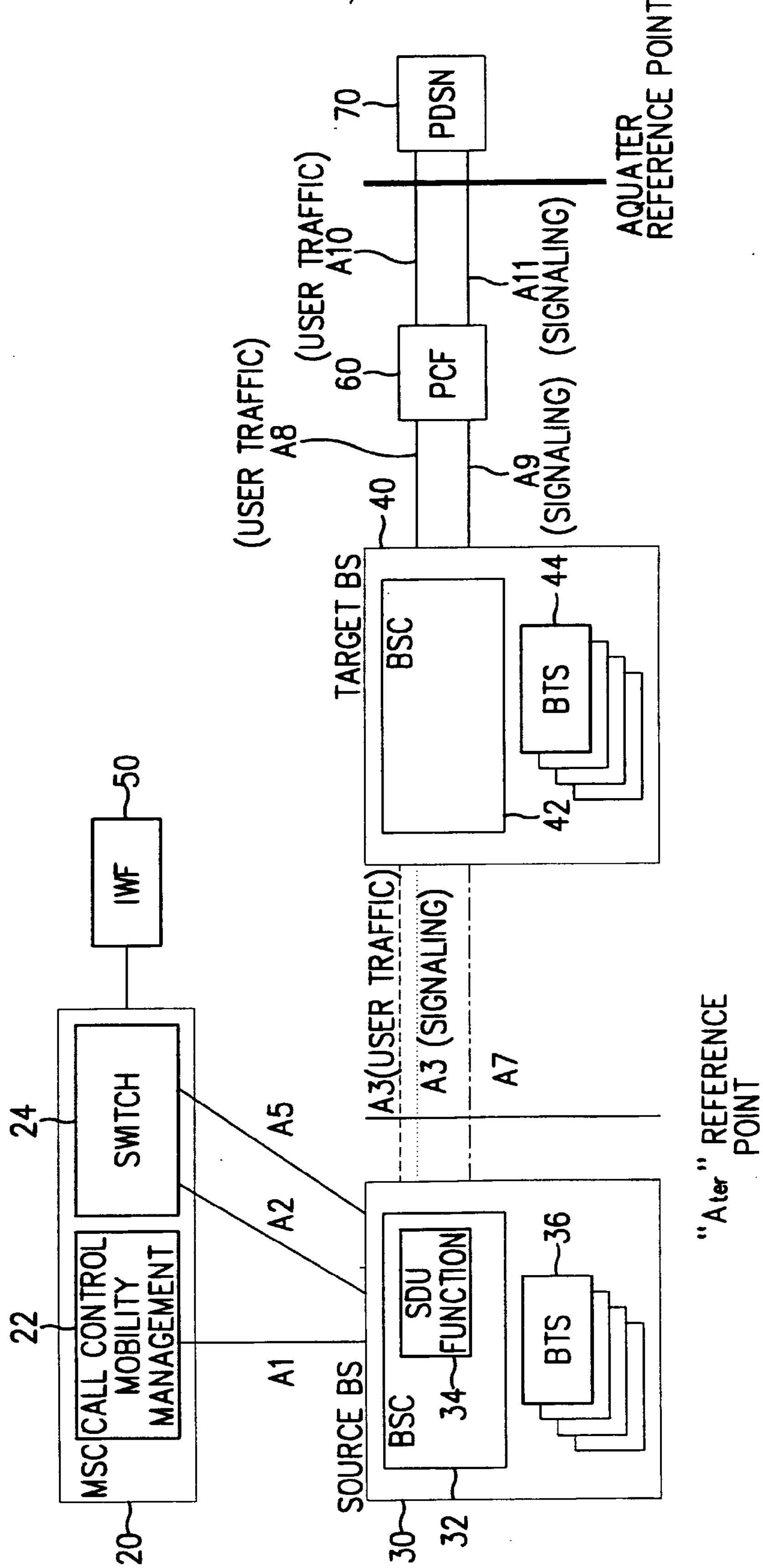
performing a slow power control if the extracted power control information is a QIB and setting the first field to a QIB status value in the reverse DCCH message;

setting a predetermined second field in the reverse DCCH message according to the energy measurement of the extracted power control information; and

transmitting the reverse DCCH message to the BSC.

15. The method of claim 14, wherein the second field is FQI (Frame Quality Indicator) information.

FIG. 1



MSC
CALL CONTROL MOBILITY MANAGEMENT
SWITCH
IWF
20
22
24
50
A1
A2
A5
SOURCE BS
BSC
SDU FUNCTION
BTS
30
32
34
36
A3(USER TRAFFIC)
A3 (SIGNALING)
A7
"Ater" REFERENCE POINT
TARGET BS
BSC
BTS
40
42
44
(USER TRAFFIC) A8
A9 (SIGNALING)
PCF
60
(USER TRAFFIC) A10
A11 (SIGNALING)
PDSN
70
AQUATER REFERENCE POINT

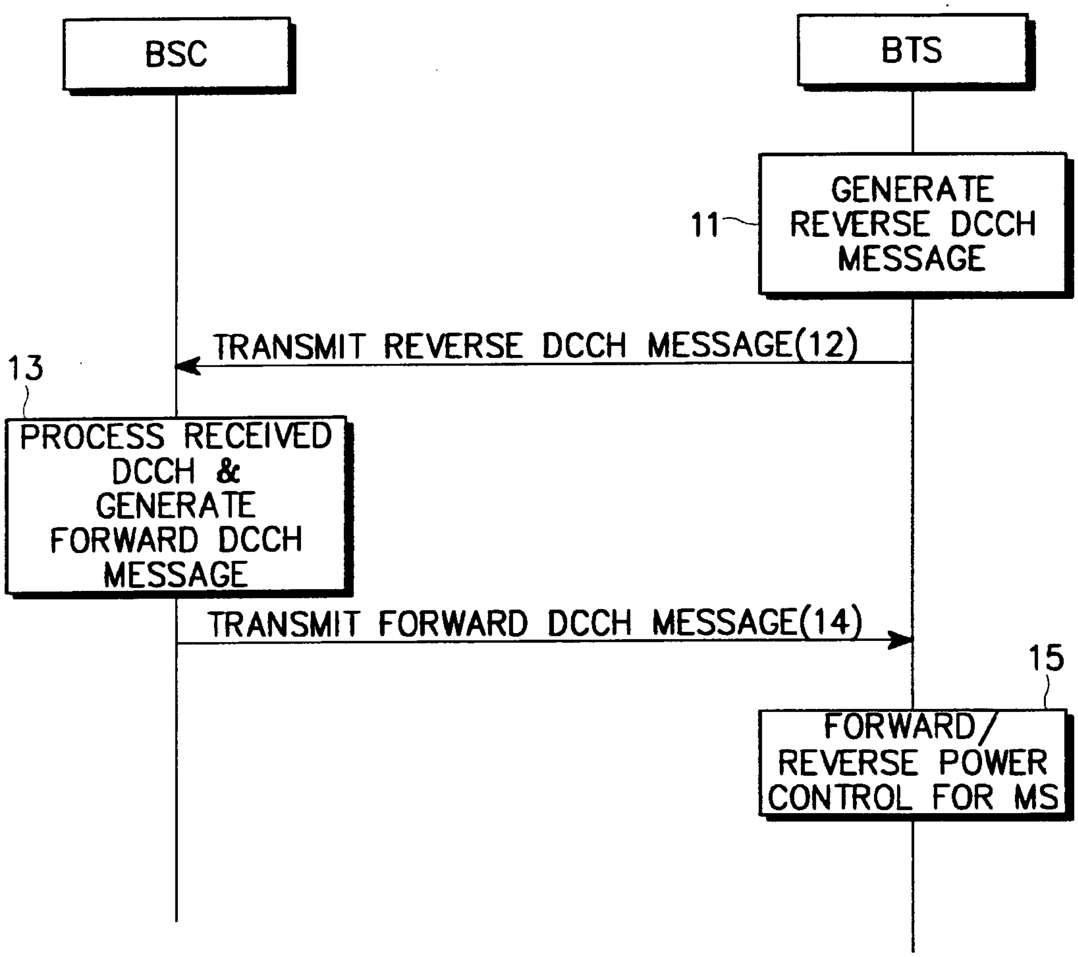

BSC
BTS
11
GENERATE REVERSE DCCH MESSAGE
TRANSMIT REVERSE DCCH MESSAGE(12)
13
PROCESS RECEIVED DCCH & GENERATE FORWARD DCCH MESSAGE
TRANSMIT FORWARD DCCH MESSAGE(14)
15
FORWARD/ REVERSE POWER CONTROL FOR MS

FIG. 2

FIG. 3A

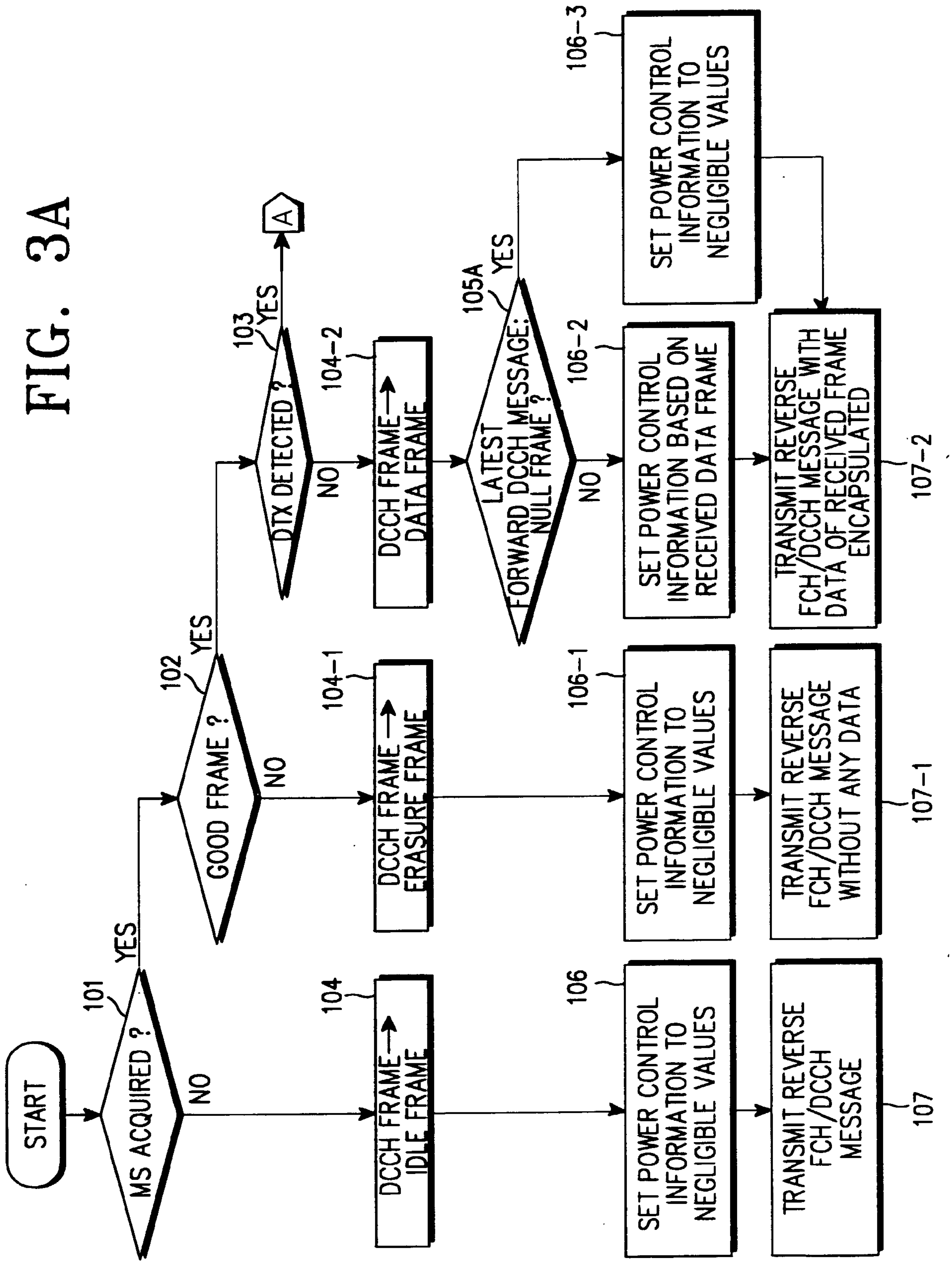

START
MS ACQUIRED ?
101
YES
NO
GOOD FRAME ?
102
YES
NO
DTX DETECTED ?
103
YES
NO
A
DCCH FRAME → IDLE FRAME
104
DCCH FRAME → ERASURE FRAME
104-1
DCCH FRAME → DATA FRAME
104-2
LATEST FORWARD DCCH MESSAGE: NULL FRAME ?
105A
YES
NO
SET POWER CONTROL INFORMATION TO NEGLIGIBLE VALUES
106
SET POWER CONTROL INFORMATION TO NEGLIGIBLE VALUES
106-1
SET POWER CONTROL INFORMATION BASED ON RECEIVED DATA FRAME
106-2
SET POWER CONTROL INFORMATION TO NEGLIGIBLE VALUES
106-3
TRANSMIT REVERSE FCH/DCCH MESSAGE
107
TRANSMIT REVERSE FCH/DCCH MESSAGE WITHOUT ANY DATA
107-1
TRANSMIT REVERSE FCH/DCCH MESSAGE WITH DATA OF RECEIVED FRAME ENCAPSULATED
107-2

FIG. 3B

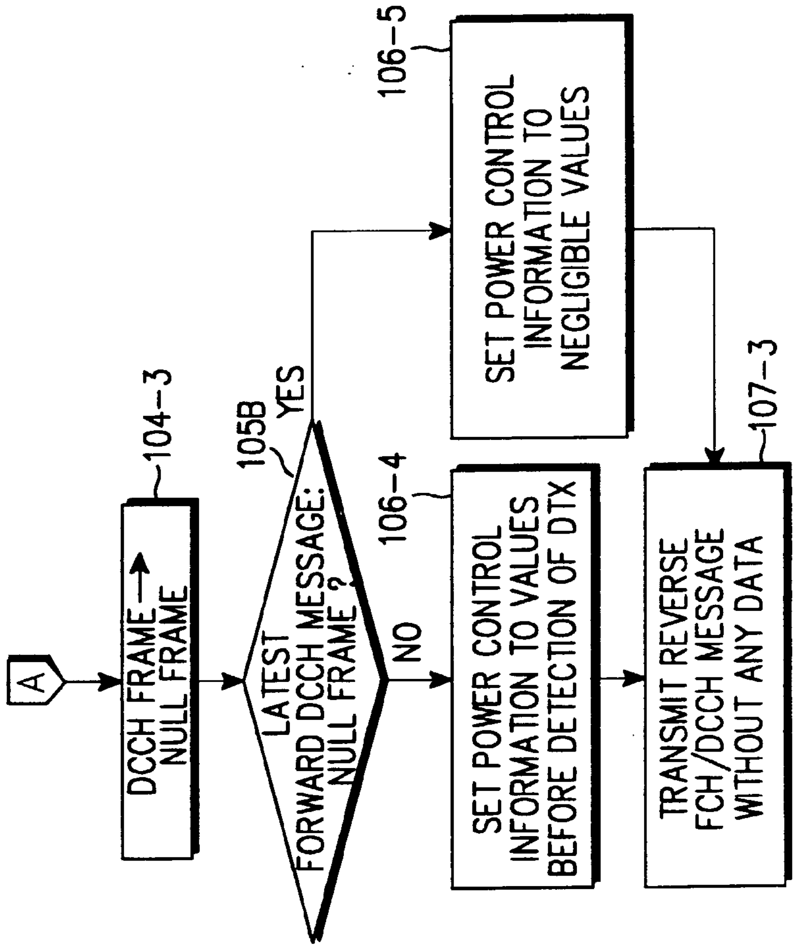

A
DCCH FRAME → NULL FRAME
104-3
105B
LATEST FORWARD DCCH MESSAGE: NULL FRAME ?
YES
NO
106-5
SET POWER CONTROL INFORMATION TO NEGLIGIBLE VALUES
106-4
SET POWER CONTROL INFORMATION TO VALUES BEFORE DETECTION OF DTX
107-3
TRANSMIT REVERSE FCH/DCCH MESSAGE WITHOUT ANY DATA

FIG. 4A

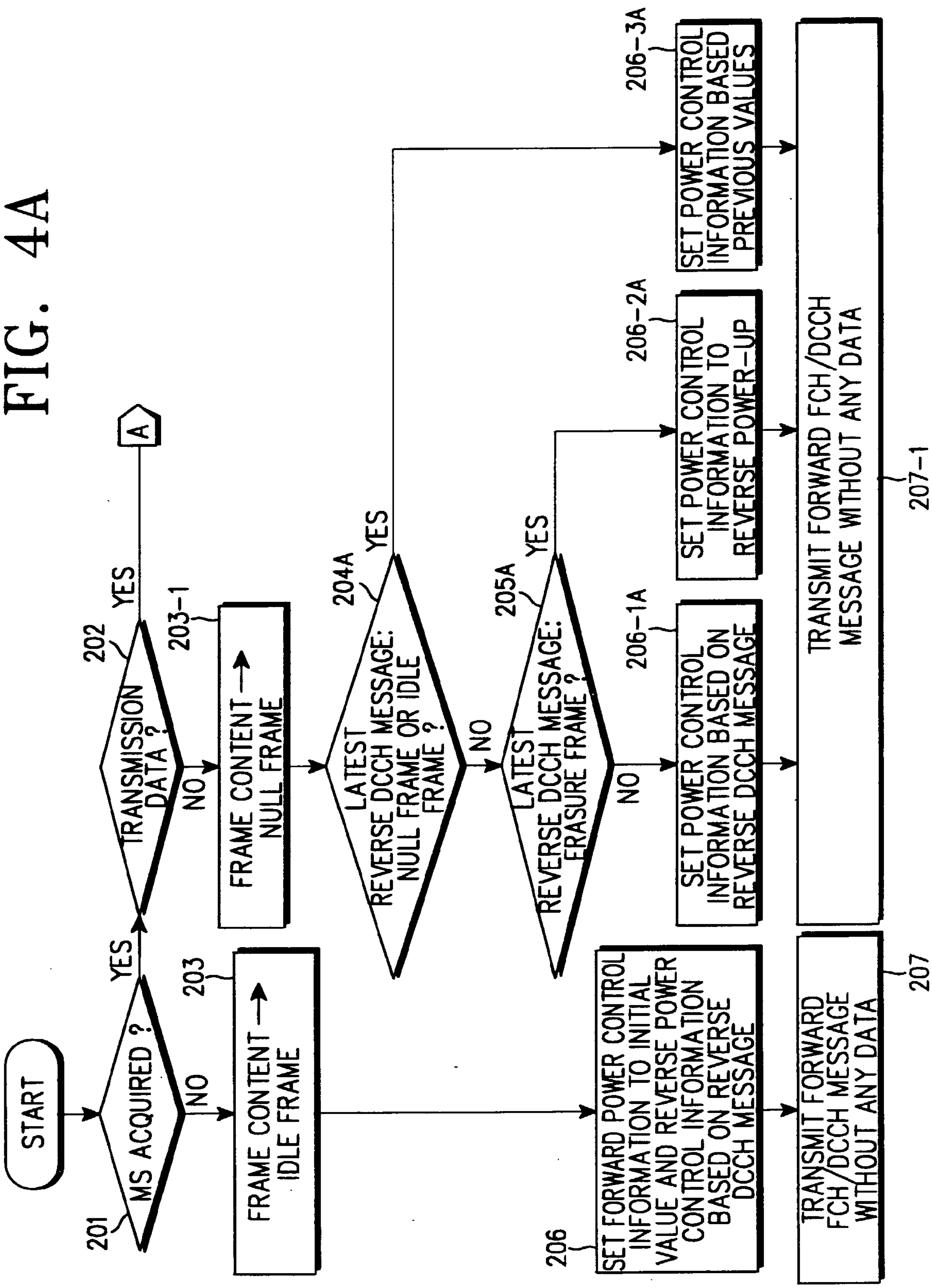

START
201
MS ACQUIRED ?
YES
NO
202
TRANSMISSION DATA ?
YES
A
NO
203
FRAME CONTENT → IDLE FRAME
203-1
FRAME CONTENT → NULL FRAME
204A
LATEST REVERSE DCCH MESSAGE: NULL FRAME OR IDLE FRAME ?
YES
NO
205A
LATEST REVERSE DCCH MESSAGE: ERASURE FRAME ?
YES
NO
206
SET FORWARD POWER CONTROL INFORMATION TO INITIAL VALUE AND REVERSE POWER CONTROL INFORMATION BASED ON REVERSE DCCH MESSAGE
206-1A
SET POWER CONTROL INFORMATION BASED ON REVERSE DCCH MESSAGE
206-2A
SET POWER CONTROL INFORMATION TO REVERSE POWER-UP
206-3A
SET POWER CONTROL INFORMATION BASED PREVIOUS VALUES
207
TRANSMIT FORWARD FCH/DCCH MESSAGE WITHOUT ANY DATA
207-1
TRANSMIT FORWARD FCH/DCCH MESSAGE WITHOUT ANY DATA

FIG. 4B

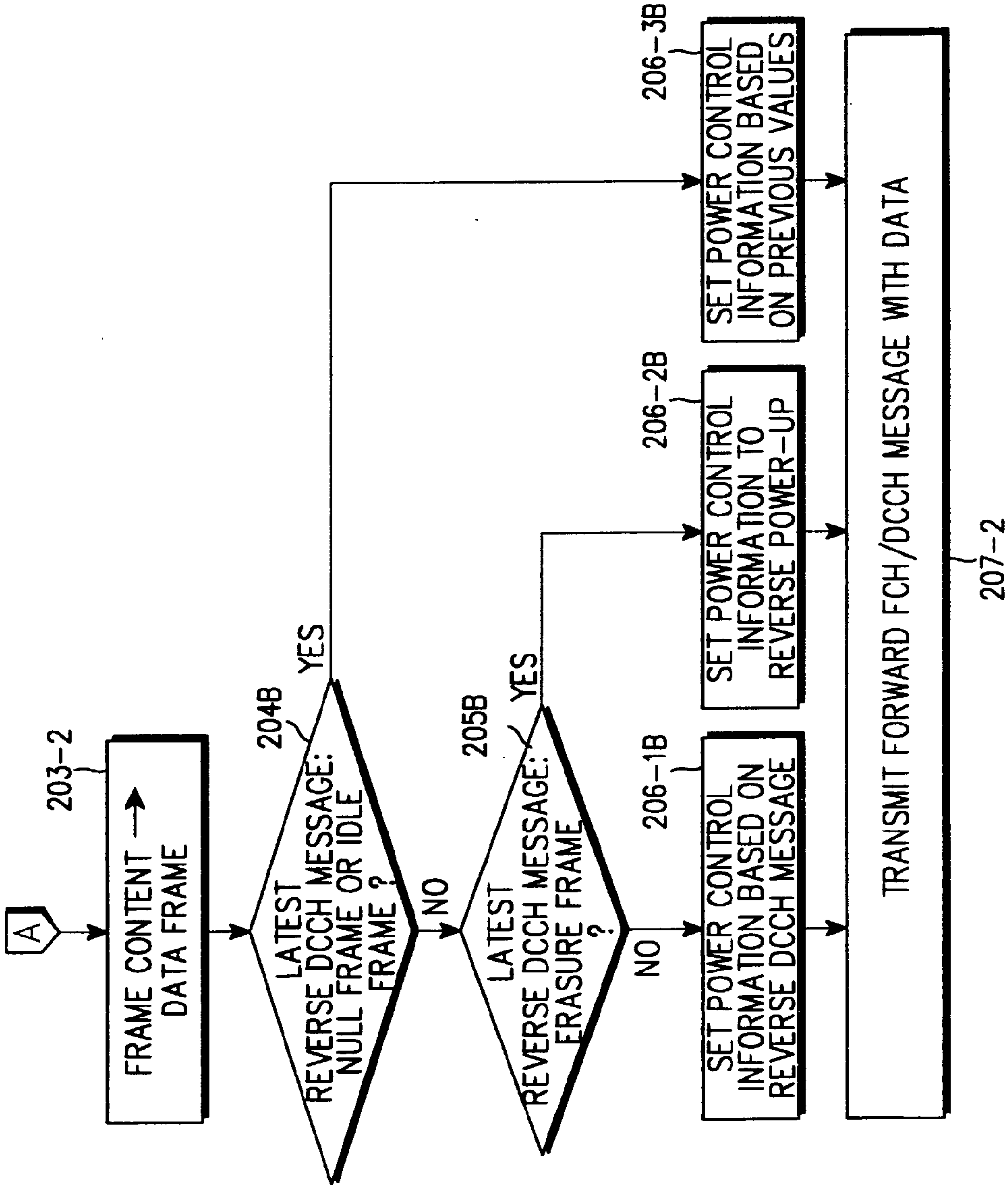

A
FRAME CONTENT → DATA FRAME
203-2
LATEST REVERSE DCCH MESSAGE: NULL FRAME OR IDLE FRAME ?
204B
YES
NO
LATEST REVERSE DCCH MESSAGE: ERASURE FRAME ?
205B
YES
NO
SET POWER CONTROL INFORMATION BASED ON REVERSE DCCH MESSAGE
206-1B
SET POWER CONTROL INFORMATION TO REVERSE POWER-UP
206-2B
SET POWER CONTROL INFORMATION BASED ON PREVIOUS VALUES
206-3B
TRANSMIT FORWARD FCH/DCCH MESSAGE WITH DATA
207-2

FIG. 5

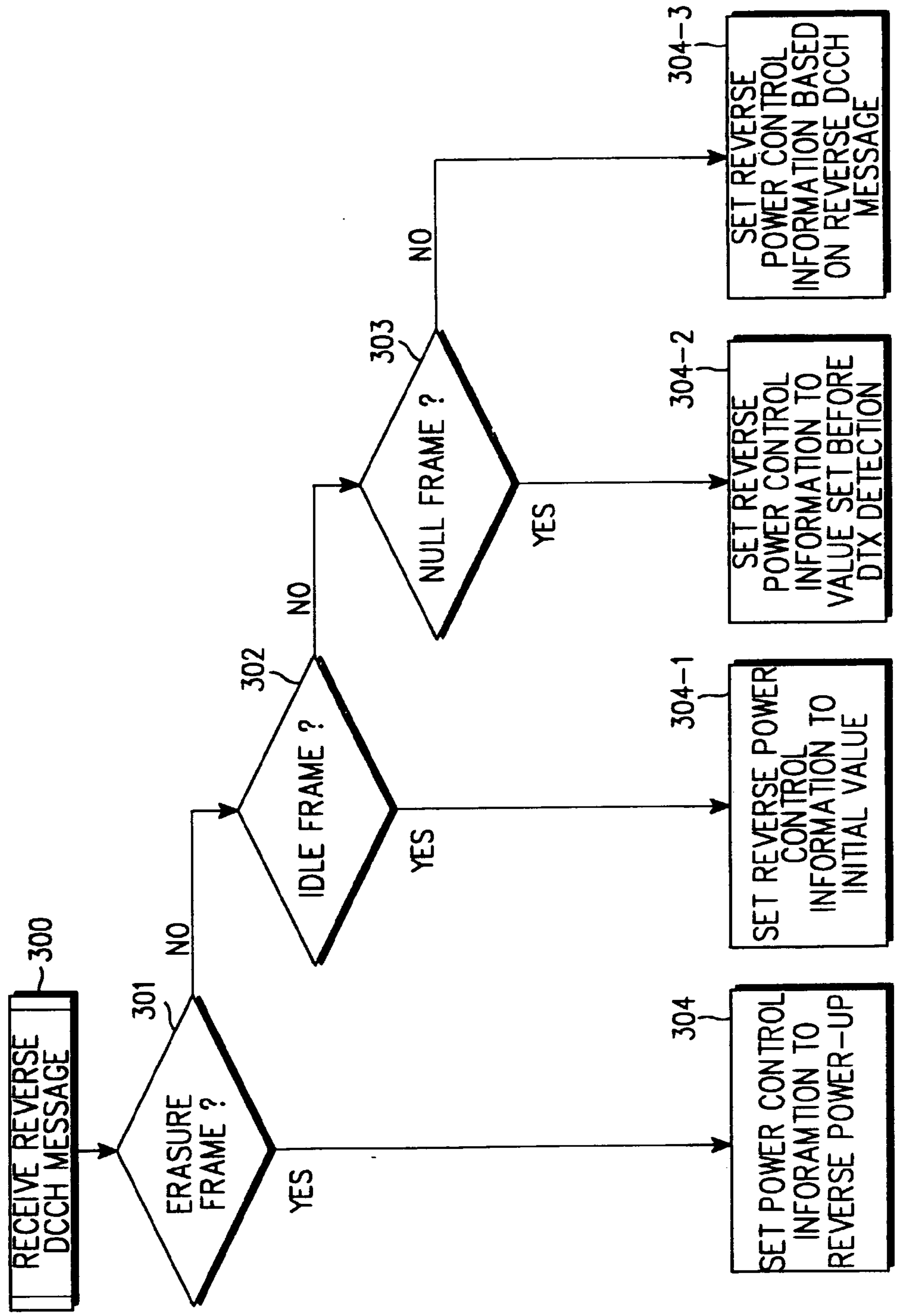

RECEIVE REVERSE DCCH MESSAGE
300
ERASURE FRAME ?
301
YES
NO
IDLE FRAME ?
302
YES
NO
NULL FRAME ?
303
YES
NO
SET POWER CONTROL INFORAMTION TO REVERSE POWER-UP
304
SET REVERSE POWER CONTROL INFORMATION TO INITIAL VALUE
304-1
SET REVERSE POWER CONTROL INFORMATION TO VALUE SET BEFORE DTX DETECTION
304-2
SET REVERSE POWER CONTROL INFORMATION BASED ON REVERSE DCCH MESSAGE
304-3

FIG. 6

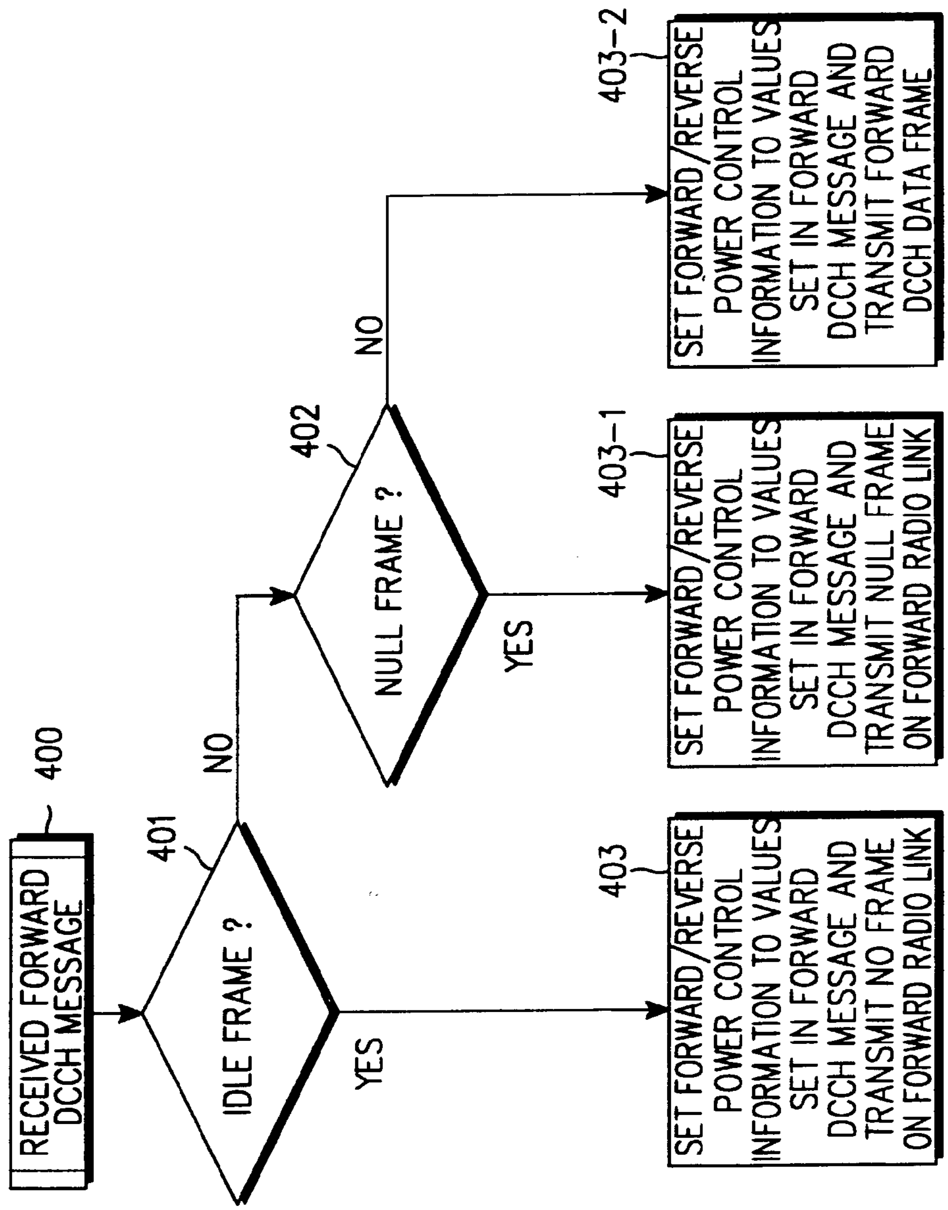

RECEIVED FORWARD DCCH MESSAGE
400
IDLE FRAME ?
401
YES
NO
NULL FRAME ?
402
YES
NO
403
SET FORWARD/REVERSE POWER CONTROL INFORMATION TO VALUES SET IN FORWARD DCCH MESSAGE AND TRANSMIT NO FRAME ON FORWARD RADIO LINK
403-1
SET FORWARD/REVERSE POWER CONTROL INFORMATION TO VALUES SET IN FORWARD DCCH MESSAGE AND TRANSMIT NULL FRAME ON FORWARD RADIO LINK
403-2
SET FORWARD/REVERSE POWER CONTROL INFORMATION TO VALUES SET IN FORWARD DCCH MESSAGE AND TRANSMIT FORWARD DCCH DATA FRAME

FIG. 7

INFORMATION ELEMENT	ELEMENT DIRECTION	TYPE
MESSAGE TYPE II	SDU → BTS	M
FORWARD LAYER 3 IS-2000 FCH/DCCH DATA	SDU → BTS	M
MESSAGE CRC	SDU → BTS	M

FIG. 8

7	6	5	4	3	2	1	0	Octet
MESSAGE TYPE II = [OEH]								1
FORWARD LAYER 3 IS-2000 FCH/DCCH DATA {1:								
FPC: SLC = [0001 TO 0110]				FSN = [0000 TO 1111]				1
FPC: GR = [OOH - FFH]								2
RPC: OLT = [OOH - FFH]								3
IS-2000 FRAME CONTENT = [OOH, 20H, 21H, 7FH]								4
(MSB)								5
FORWARD LINK INFORMATION = <VARIABLE>								
							(LSB)	n
} FORWARD LAYER 3 IS-2000 FCH/DCCH DATA								
(MSB)	MESSAGE CRC = [0000H-FFFFH]							1
							(LSB)	2

FIG. 9

INFORMATION ELEMENT	ELEMENT DIRECTION	TYPE
MESSAGE TYPE II	SDU ← BTS	M
REVERSE LAYER 3 IS-2000 FCH/DCCH DATA	SDU ← BTS	M
MESSAGE CRC	SDU ← BTS	M

FIG. 10

7	6	5	4	3	2	1	0	Octet
MESSAGE TYPE II = [OEH]								1
REVERSE LAYER 3 IS–2000 FCH/DCCH DATA {1:								
SOFT HANDOFF LEG # =[000 – 1111]				FSN = [000 to 1111]				1
CRC =[0,1]	REVERSE LINK QUALITY = [000 0000 111 1111]							2
SCALING =[00 11]		PACKET ARRIVAL TIME ERROR =[00 0000 11 1111]						3
IS–2000 FRAME CONTENT = [00H, 20H, 21H, 7EH, 7FH]								4
FPC: SNR = [0000 000 1111 111]							EIB =[0,1]	5
(MSB)								6
REVERSE LINK INFORMATION = <VARIABLE>								
							(LSB)	n
} REVERSE LAYER 3 IS–2000 FCH/DCCH DATA								
(MSB)	MESSAGE CRC = [0000H–FFFFH]							1
							(LSB)	2

FIG. 11A

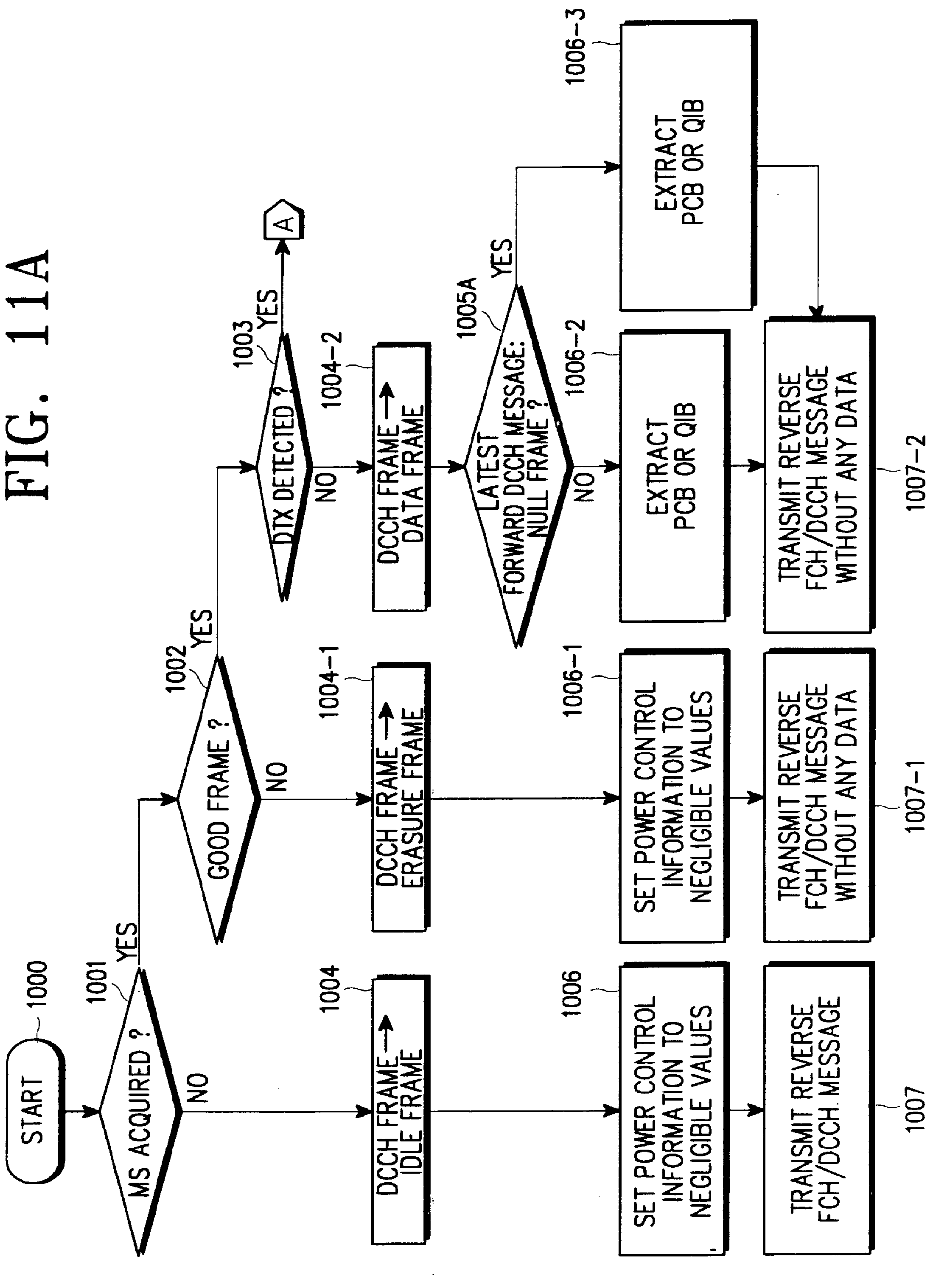

START
1000
MS ACQUIRED ?
1001
YES
NO
DCCH FRAME → IDLE FRAME
1004
SET POWER CONTROL INFORMATION TO NEGLIGIBLE VALUES
1006
TRANSMIT REVERSE FCH/DCCH MESSAGE
1007
GOOD FRAME ?
1002
YES
NO
DCCH FRAME → ERASURE FRAME
1004-1
SET POWER CONTROL INFORMATION TO NEGLIGIBLE VALUES
1006-1
TRANSMIT REVERSE FCH/DCCH MESSAGE WITHOUT ANY DATA
1007-1
DTX DETECTED ?
1003
YES
A
NO
DCCH FRAME → DATA FRAME
1004-2
LATEST FORWARD DCCH MESSAGE: NULL FRAME ?
1005A
YES
NO
EXTRACT PCB OR QIB
1006-2
TRANSMIT REVERSE FCH/DCCH MESSAGE WITHOUT ANY DATA
1007-2
EXTRACT PCB OR QIB
1006-3

FIG. 11B

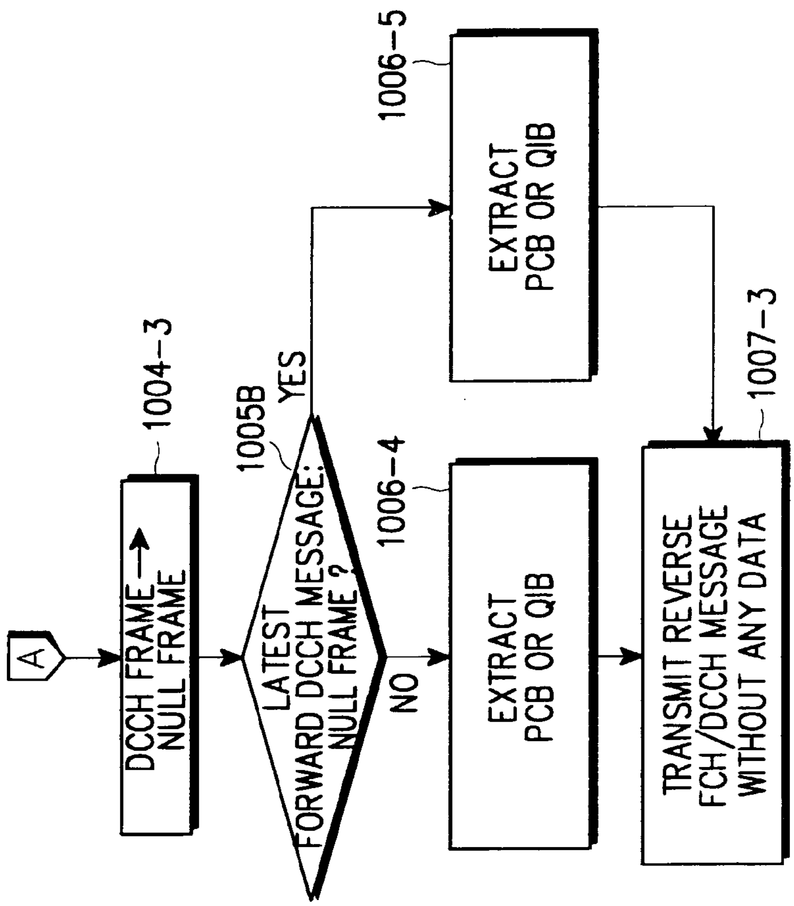

A
DCCH FRAME → NULL FRAME
1004-3
LATEST FORWARD DCCH MESSAGE; NULL FRAME ?
1005B
YES
NO
EXTRACT PCB OR QIB
1006-4
EXTRACT PCB OR QIB
1006-5
TRANSMIT REVERSE FCH/DCCH MESSAGE WITHOUT ANY DATA
1007-3

FIG. 12

INFORMATION ELEMENT	ELEMENT DIRECTION	TYPE
MESSAGE TYPE II	SDU ← BTS	M
REVERSE LAYER 3 IS-2000 FCH/DCCH DATA	SDU ← BTS	M
MESSAGE CRC	SDU ← BTS	M

FIG. 13

7	6	5	4	3	2	1	0	Octet
MESSAGE TYPE II = [OEH]								1
REVERSE LAYER 3 IS-2000 FCH/DCCH DATA {1:								
SOFT HANDOFF LEG # =[0000 - 1111]				FSN = [0000 to 1111]				1
FQI =[0,1]	REVERSE LINK QUALITY = [000 0000 111 1111]							2
SCALING =[00 11]		PACKET ARRIVAL TIME ERROR =[00 0000 11 1111]						3
IS-2000 FRAME CONTENT = [00H, 20H, 21H, 7EH, 7FH]								4
FPC: SNR = [0000 000 1111 111]							QIB/EIB =[0,1]	5
(MSB)								6
REVERSE LINK INFORMATION = <VARIABLE>								
							(LSB)	n
} REVERSE LAYER 3 IS-2000 FCH/DCCH DATA								
(MSB)	MESSAGE CRC = [0000H-FFFFH]							1
							(LSB)	2

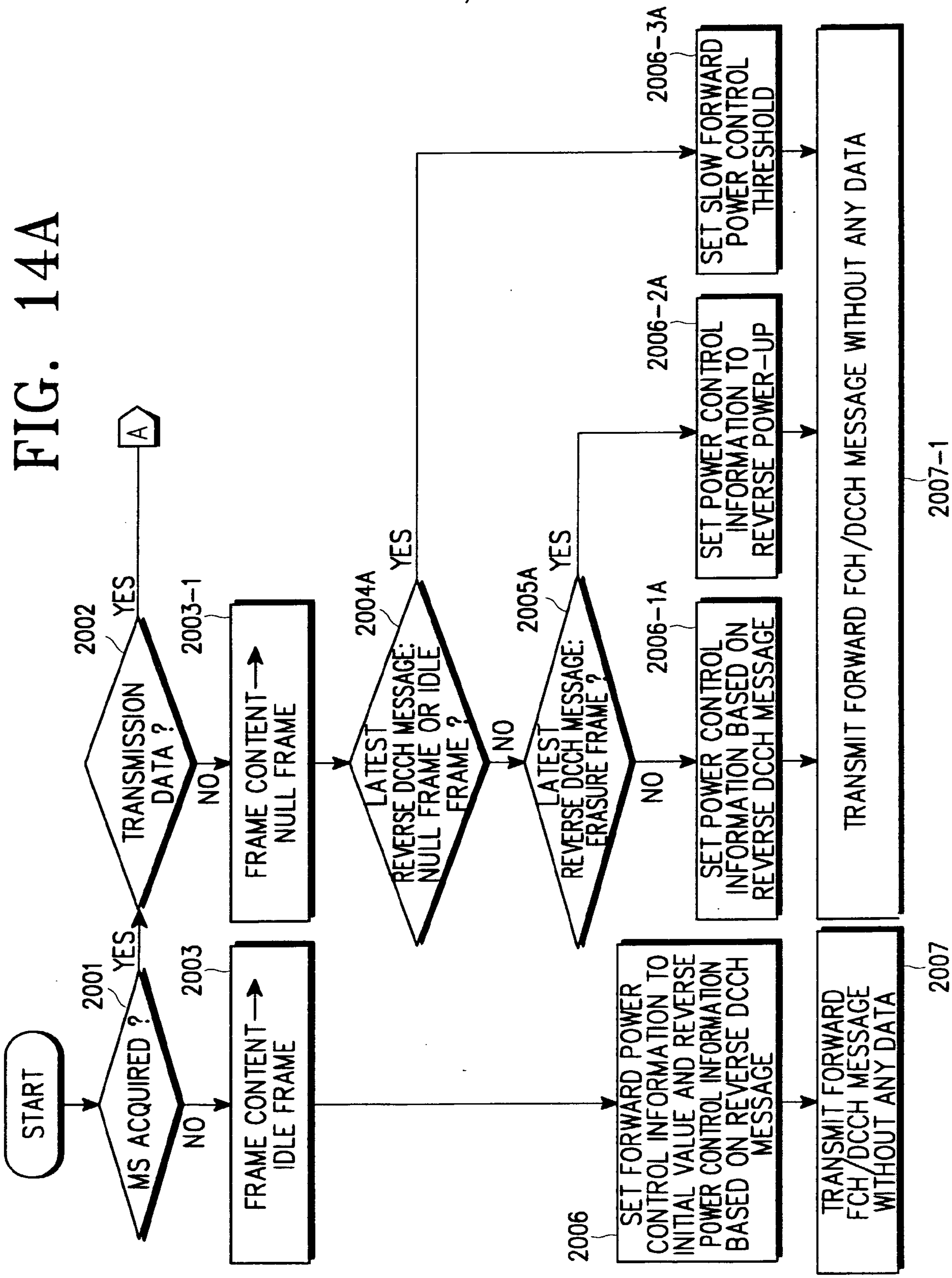

START
MS ACQUIRED ?
2001
YES
NO
FRAME CONTENT⟶ IDLE FRAME
2003
TRANSMISSION DATA ?
2002
YES
A
NO
FRAME CONTENT⟶ NULL FRAME
2003-1
LATEST REVERSE DCCH MESSAGE: NULL FRAME OR IDLE FRAME ?
2004A
YES
NO
LATEST REVERSE DCCH MESSAGE: ERASURE FRAME ?
2005A
YES
NO
SET FORWARD POWER CONTROL INFORMATION TO INITIAL VALUE AND REVERSE POWER CONTROL INFORMATION BASED ON REVERSE DCCH MESSAGE
2006
SET POWER CONTROL INFORMATION BASED ON REVERSE DCCH MESSAGE
2006-1A
SET POWER CONTROL INFORMATION TO REVERSE POWER-UP
2006-2A
SET SLOW FORWARD POWER CONTROL THRESHOLD
2006-3A
TRANSMIT FORWARD FCH/DCCH MESSAGE WITHOUT ANY DATA
2007
TRANSMIT FORWARD FCH/DCCH MESSAGE WITHOUT ANY DATA
2007-1

FIG. 14A

FIG. 14B

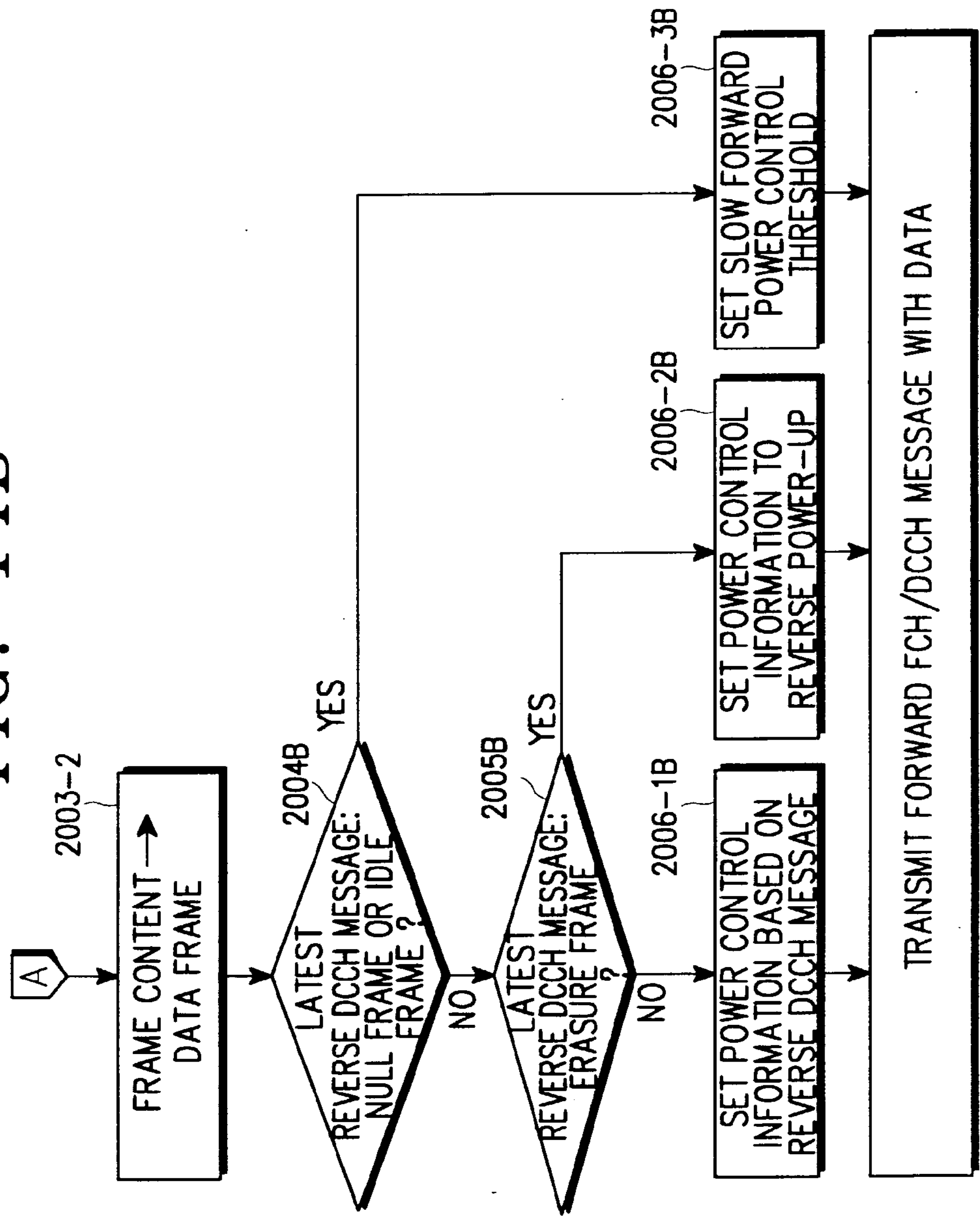

A
FRAME CONTENT → DATA FRAME
2003-2
LATEST REVERSE DCCH MESSAGE: NULL FRAME OR IDLE FRAME ?
2004B
YES
NO
LATEST REVERSE DCCH MESSAGE: ERASURE FRAME ?
2005B
YES
NO
SET POWER CONTROL INFORMATION BASED ON REVERSE DCCH MESSAGE
2006-1B
SET POWER CONTROL INFORMATION TO REVERSE POWER-UP
2006-2B
SET SLOW FORWARD POWER CONTROL THRESHOLD
2006-3B
TRANSMIT FORWARD FCH/DCCH MESSAGE WITH DATA
2007-2

FIG. 15

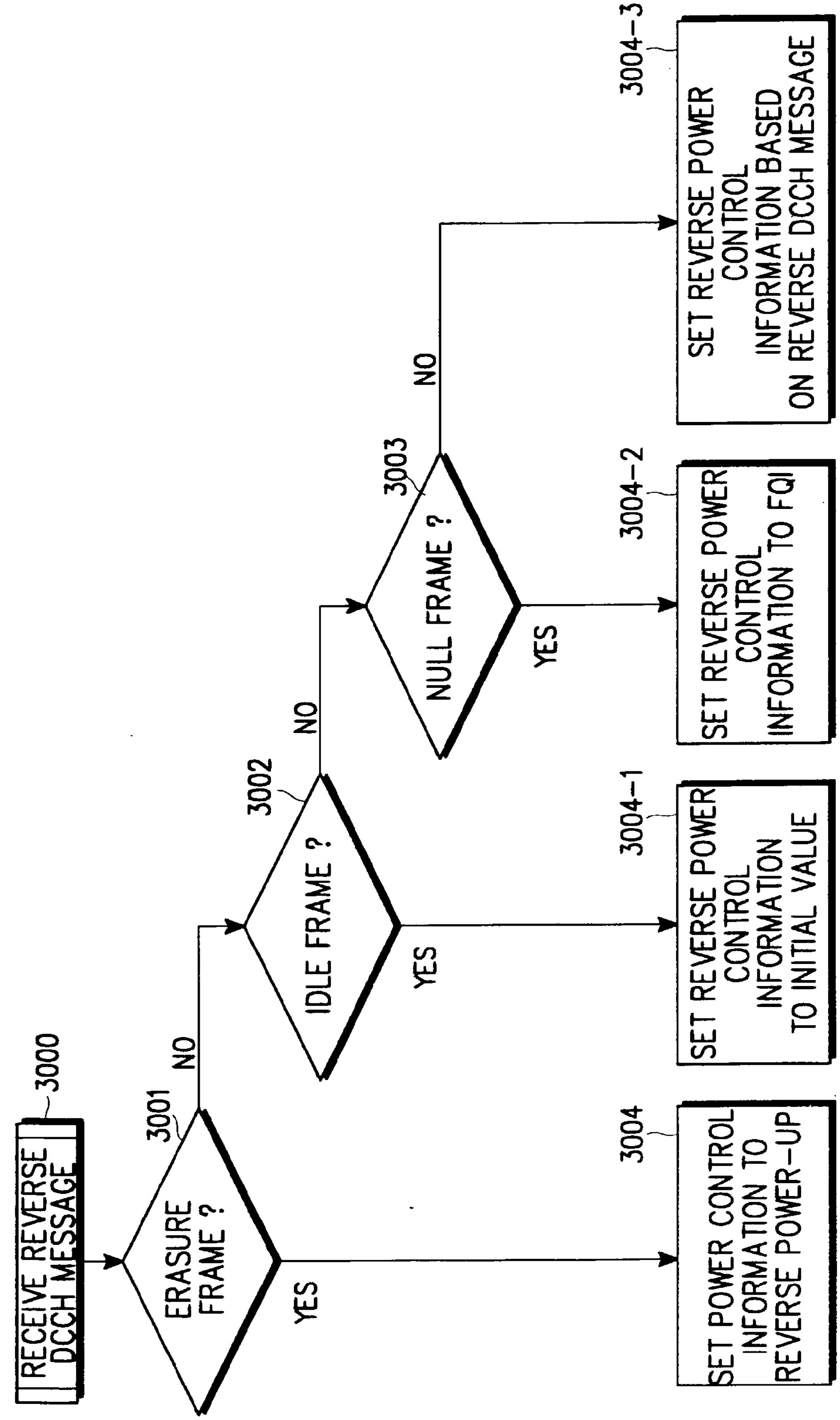

RECEIVE REVERSE DCCH MESSAGE
3000
ERASURE FRAME ?
3001
YES
NO
IDLE FRAME ?
3002
YES
NO
NULL FRAME ?
3003
YES
NO
SET POWER CONTROL INFORMATION TO REVERSE POWER-UP
3004
SET REVERSE POWER CONTROL INFORMATION TO INITIAL VALUE
3004-1
SET REVERSE POWER CONTROL INFORMATION TO FQI
3004-2
SET REVERSE POWER CONTROL INFORMATION BASED ON REVERSE DCCH MESSAGE
3004-3

FIG. 16

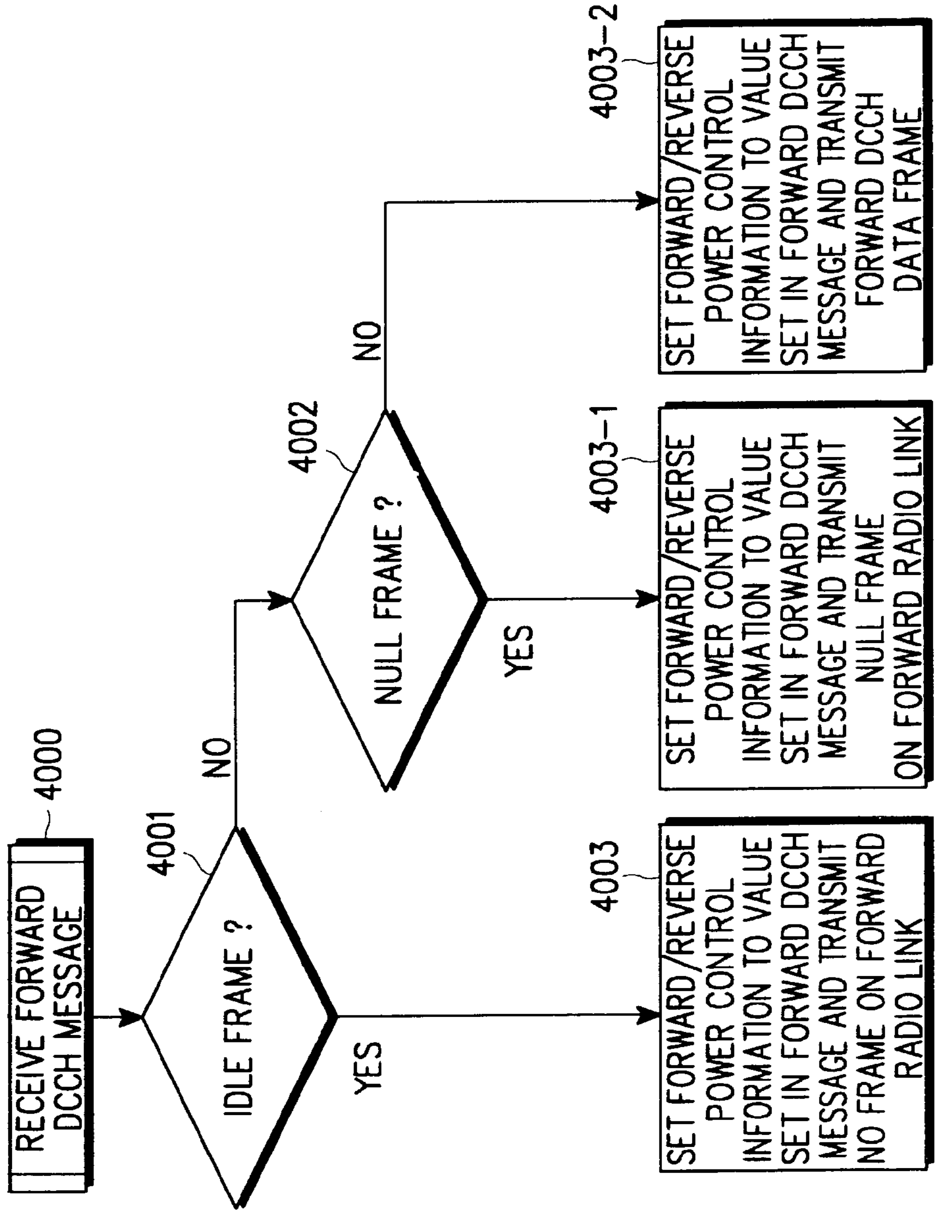

RECEIVE FORWARD DCCH MESSAGE
4000
IDLE FRAME ?
4001
YES
NO
NULL FRAME ?
4002
YES
NO
SET FORWARD/REVERSE POWER CONTROL INFORMATION TO VALUE SET IN FORWARD DCCH MESSAGE AND TRANSMIT NO FRAME ON FORWARD RADIO LINK
4003
SET FORWARD/REVERSE POWER CONTROL INFORMATION TO VALUE SET IN FORWARD DCCH MESSAGE AND TRANSMIT NULL FRAME ON FORWARD RADIO LINK
4003-1
SET FORWARD/REVERSE POWER CONTROL INFORMATION TO VALUE SET IN FORWARD DCCH MESSAGE AND TRANSMIT FORWARD DCCH DATA FRAME
4003-2

FIG. 17A

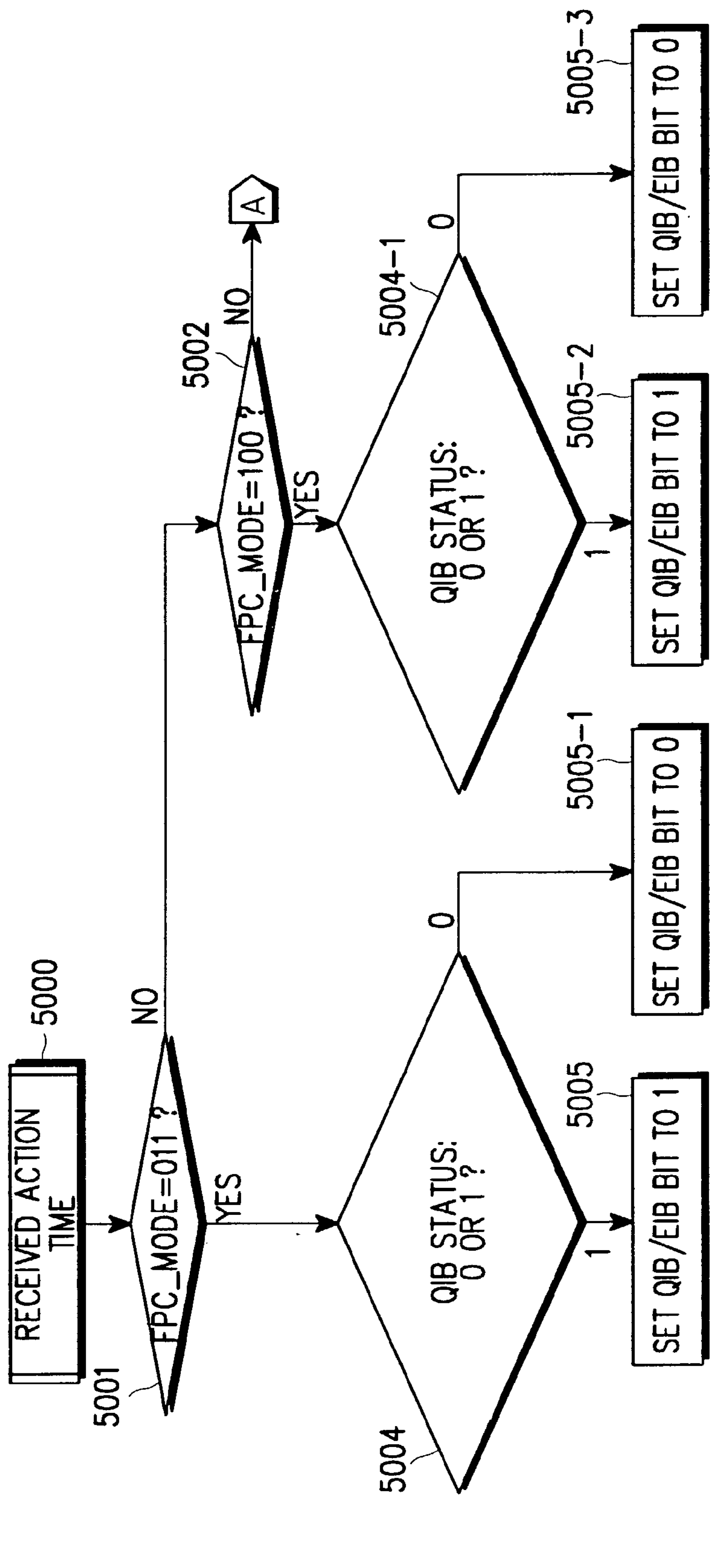

RECEIVED ACTION TIME
5000
5001
FPC_MODE=011 ?
YES
NO
5002
FPC_MODE=100 ?
YES
NO
A
5004
QIB STATUS: 0 OR 1 ?
1
0
5004-1
QIB STATUS: 0 OR 1 ?
1
0
5005
SET QIB/EIB BIT TO 1
5005-1
SET QIB/EIB BIT TO 0
5005-2
SET QIB/EIB BIT TO 1
5005-3
SET QIB/EIB BIT TO 0

FIG. 17B

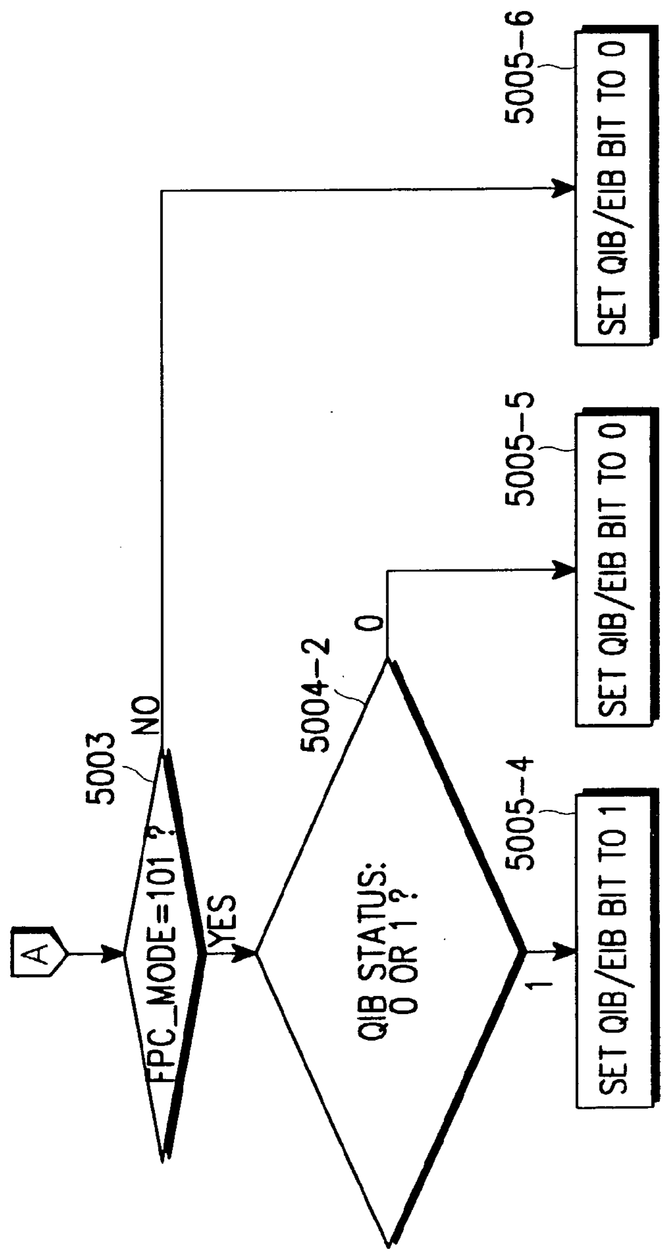

A
FPC_MODE=101 ?
5003
NO
YES
QIB STATUS:
0 OR 1 ?
5004-2
0
1
SET QIB/EIB BIT TO 1
5005-4
SET QIB/EIB BIT TO 0
5005-5
SET QIB/EIB BIT TO 0
5005-6

FIG. 18

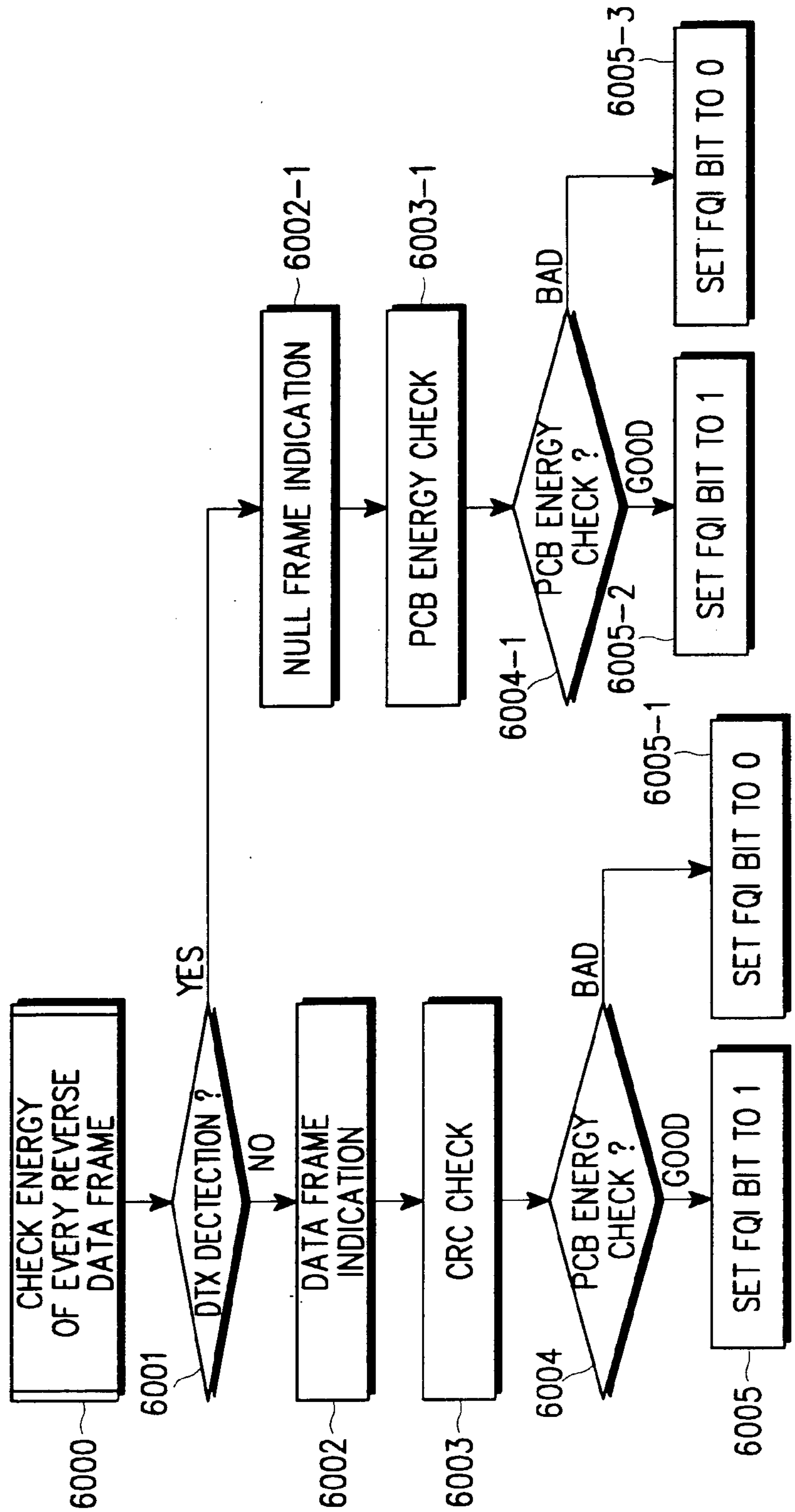

CHECK ENERGY OF EVERY REVERSE DATA FRAME
6000
DTX DECTECTION ?
6001
YES
NO
DATA FRAME INDICATION
6002
CRC CHECK
6003
PCB ENERGY CHECK ?
6004
GOOD
BAD
SET FQI BIT TO 1
6005
SET FQI BIT TO 0
6005-1
NULL FRAME INDICATION
6002-1
PCB ENERGY CHECK
6003-1
PCB ENERGY CHECK ?
6004-1
GOOD
BAD
SET FQI BIT TO 1
6005-2
SET FQI BIT TO 0
6005-3

FIG. 19

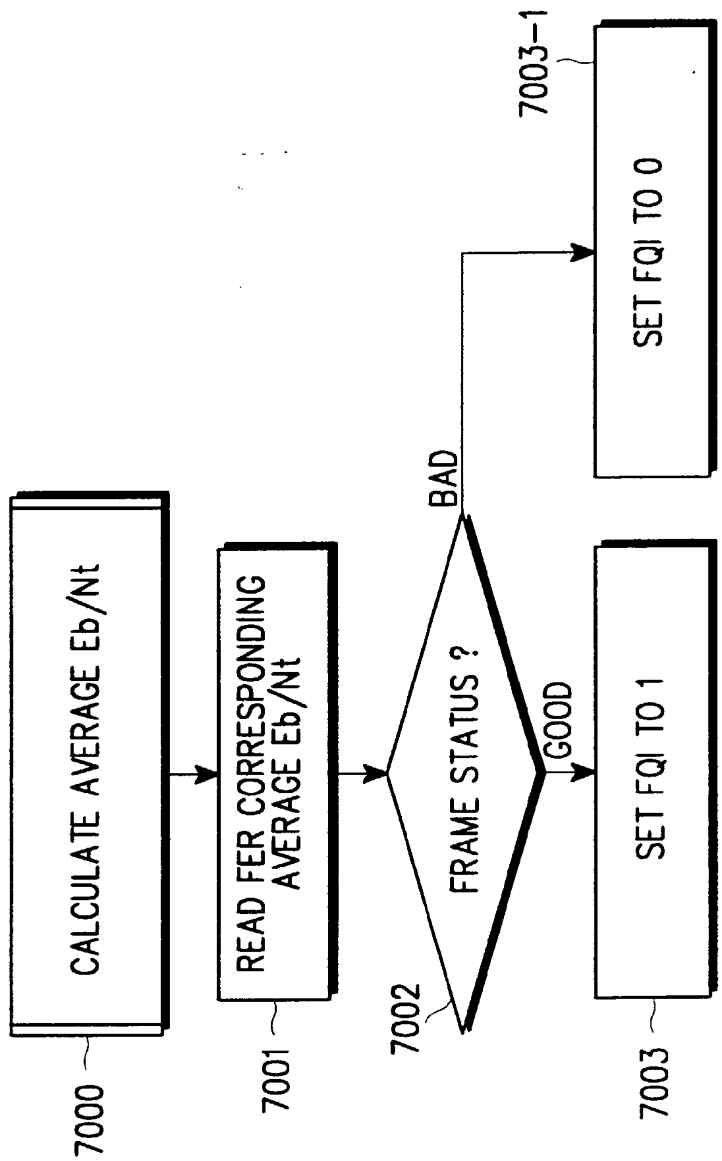
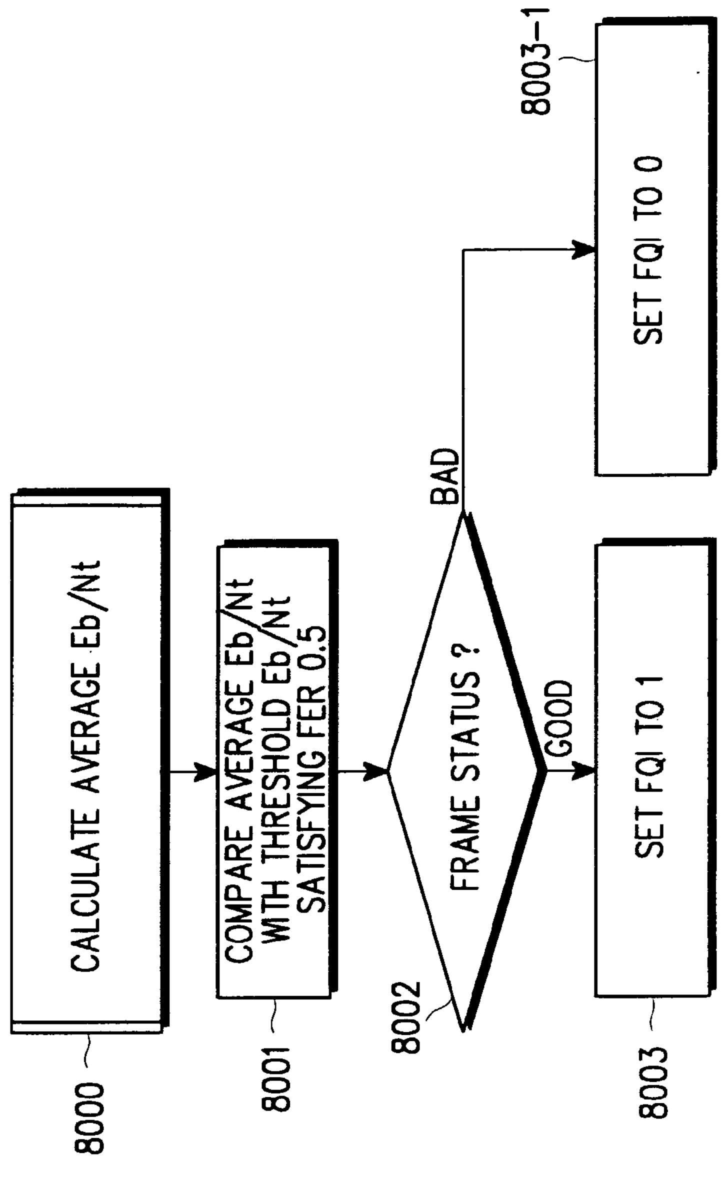

CALCULATE AVERAGE Eb/Nt
7000
READ FER CORRESPONDING AVERAGE Eb/Nt
7001
FRAME STATUS ?
7002
BAD
GOOD
SET FQI TO 0
7003-1
SET FQI TO 1
7003

FIG. 20


CALCULATE AVERAGE Eb/Nt
8000
COMPARE AVERAGE Eb/Nt WITH THRESHOLD Eb/Nt SATISFYING FER 0.5
8001
FRAME STATUS ?
8002
BAD
GOOD
SET FQI TO 1
8003
SET FQI TO 0
8003-1

INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR01/00700

A. CLASSIFICATION OF SUBJECT MATTER

IPC7 H04B 7/26

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimun documentation searched (classification system followed by classification symbols)

IPC7 H04B 7, H04Q

Documentation searched other than minimun documentation to the extent that such documents are included in the fileds searched

Korean Patents and applications for inventions since 1975
Korean Utility models and applications for Utility models since 1975

Electronic data base consulted during the intertnational search (name of data base and, where practicable, search trerms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 98/36508 A (NOKIA TELECOMMUNICATIONS) 20 AUGUST 1998 See the whole document	1 - 15
A	WO 98/58461 A (ERICSSON TELEFON AB L M.) 23 DECEMBER 1998 See the whole document	1 - 15
A	KR 99-83484 A (SAMSUNG CORP.) 25 NOVEMBER 1999 See the whole document	1 - 15
A	WO 98/56120 A (ERICSSON TELEFON AB L M.) 10 DECEMBER 1998 See the whole document	1 - 15

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevence
"E" earlier application or patent but published on or after the international filing date
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"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevence; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevence; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
16 AUGUST 2001 (16.08.2001)	17 AUGUST 2001 (17.08.2001)

Name and mailing address of the ISA/KR	Authorized officer
Korean Intellectual Property Office Government Complex-Daejeon, Dunsan-dong, Seo-gu, Daejeon Metropolitan City 302-701, Republic of Korea	YOON, Byoung Soo
Facsimile No. 82-42-472-7140	Telephone No. 82-42-481-5709

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
PCT/KR01/00700

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 98/36508 A	20. 08. 1998	AU 5666098 A EP 0914722 A	08. 09. 1998 12. 05. 1999
WO 98/58461 A	23. 12. 1998	AU 8050198 A	04. 01. 1999
KR 99-83484 A	25. 11. 1999	NONE	NONE
WO 98/56120 A	10. 12. 1998	AU 8048298 A	21. 12. 1998

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PUB DATE: 2002-06-20
APPLICANT : Broadstrom Telecommunications, Inc. [US]

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JP2005502218
PUB DATE: 2005-01-20
APPLICANT: BROADSTORM TELECOMMUNICATIONS [US]

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

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(25) Filing Language: English

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09/738,086 15 December 2000 (15.12.2000) US

(71) Applicant: BROADSTROM TELECOMMUNICATIONS, INC. [US/US]; 400 112TH Avenue NE, Suite 250, Bellevue, WA 98004 (US).

(72) Inventors: **LIU, Hui**; 2708 226th Avenue, SE, Sammamish, WA 98075 (US). **LI, Kemin**; 14733 NE 1st Place #E6, Bellevue, WA 98007 (US). **LI, Xiaodong**; 13075 SE 26th, Apt. E208, Bellevue, WA 98005 (US). **ZHANG, Wenzhong**; 4275 148th Avenue, NE, F20, Bellevue, WA 98007 (US).

(74) Agents: **MALLIE, Michael, J.** et al.; Blakely, Sokoloff, Taylor & Zafman LLP, 7th floor, 12400 Wilshire Boulevard, Los Angeles, CA 90025 (US).

(81) Designated States *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, OM, PH, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, UZ, VN, YU, ZA, ZM, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *without international search report and to be republished upon receipt of that report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

WO 02/49305 A2

(54) **Title:** OFDMA WITH ADAPTIVE SUBCARRIER-CLUSTER CONFIGURATION AND SELECTIVE LOADING

(57) **Abstract:** A method and apparatus for subcarrier selection for systems is described. In one embodiment, the system employs orthogonal frequency division multiple access (OFDMA). In one embodiment, a method for subcarrier selection compreses each of multiple subscribes measuring channel and interference information for subcarriers based on pilot symbols received from a base station, at least one of subscribers selecting a set of candidate subcarriers, providing feedback information on the set of candidate subcarriers to the base station, andthe one subscriber receiving an indicaiton of subcarriers to the base station, and the one subscriber receiving an indication of subcarriers of the set of subcarriers selected bz the base station for use by the one subscriber.

OFDMA WITH ADAPTIVE SUBCARRIER-CLUSTER CONFIGURATION AND SELECTIVE LOADING

FIELD OF THE INVENTION

The invention relates to the field of wireless communications; more particularly, the invention relates to multi-cell, multi-subscriber wireless systems using orthogonal frequency division multiplexing (OFDM).

BACKGROUND OF THE INVENTION

Orthogonal frequency division multiplexing (OFDM) is an efficient modulation scheme for signal transmission over frequency-selective channels. In OFDM, a wide bandwidth is divided into multiple narrow-band subcarriers, which are arranged to be orthogonal with each other. The signals modulated on the subcarriers are transmitted in parallel. For more information, see Cimini, Jr., "Analysis and Simulation of a Digital Mobile Channel Using Orthogonal Frequency Division Multiplexing," IEEE Trans. Commun., vol. COM-33, no. 7, July 1985, pp. 665-75; Chuang and Sollenberger, "Beyond 3G: Wideband Wireless Data Access Based on OFDM and Dynamic Packet Assignment," IEEE Communications Magazine, Vol. 38, No. 7, pp. 78–87, July 2000.

One way to use OFDM to support multiple access for multiple subscribers is through time division multiple access (TDMA), in which each subscriber uses all the subcarriers within its assigned time slots. Orthogonal frequency division multiple access (OFDMA) is another method for multiple access, using the basic format of OFDM. In OFDMA, multiple subscribers simultaneously use different subcarriers, in a fashion similar to frequency division multiple access (FDMA). For more information, see Sari and Karam, "Orthogonal Frequency-Division Multiple Access and its Application to CATV Networks," European Transactions on Telecommunications, Vol. 9 (6), pp. 507-516, Nov./Dec. 1998 and Nogueroles, Bossert, Donder, and Zyablov, "Improved Performance of a Random OFDMA Mobile Communication System,", Proceedings of IEEE VTC'98, pp. 2502 –2506.

Multipath causes frequency-selective fading. The channel gains are different for different subcarriers. Furthermore, the channels are typically uncorrelated for different subscribers. The subcarriers that are in deep fade for one subscriber may provide high channel gains for another subscriber. Therefore, it is advantageous in an OFDMA

system to adaptively allocate the subcarriers to subscribers so that each subscriber enjoys a high channel gain. For more information, see Wong et al., "Multiuser OFDM with Adaptive Subcarrier, Bit and Power Allocation," IEEE J. Select. Areas Commun., Vol. 17(10), pp. 1747-1758, October 1999.

Within one cell, the subscribers can be coordinated to have different subcarriers in OFDMA. The signals for different subscribers can be made orthogonal and there is little intracell interference. However, with aggressive frequency reuse plan, e.g., the same spectrum is used for multiple neighboring cells, the problem of intercell interference arises. It is clear that the intercell interference in an OFDMA system is also frequency selective and it is advantageous to adaptively allocate the subcarriers so as to mitigate the effect of intercell interference.

One approach to subcarrier allocation for OFDMA is a joint optimization operation, not only requiring the activity and channel knowledge of all the subscribers in all the cells, but also requiring frequent rescheduling every time an existing subscribers is dropped off the network or a new subscribers is added onto the network. This is often impractical in real wireless system, mainly due to the bandwidth cost for updating the subscriber information and the computation cost for the joint optimization.

SUMMARY OF THE INVENTION

A method and apparatus for subcarrier selection for systems is described. In one embodiment, the system employs orthogonal frequency division multiple access (OFDMA). In one embodiment, a method for subcarrier selection comprises a subscriber measuring channel and interference information for subcarriers based on pilot symbols received from a base station, the subscriber selecting a set of candidate subcarriers, providing feedback information on the set of candidate subcarriers to the base station, and receiving an indication of subcarriers of the set of subcarriers selected by the base station for use by the subscriber.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be understood more fully from the detailed description given below and from the accompanying drawings of various embodiments of the invention, which, however, should not be taken to limit the invention to the specific embodiments, but are for explanation and understanding only.

Figure 1A illustrates subcarriers and clusters.

Figure 1B is a flow diagram of one embodiment of a process for allocating subcarriers.

Figure 2 illustrates time and frequency grid of OFDM symbols, pilots and clusters.

Figure 3 illustrates subscriber processing.

Figure 4 illustrates one example of Figure 3.

Figure 5 illustrates one embodiment of a format for arbitrary cluster feedback.

Figure 6 illustrates one embodiment of a partition the clusters into groups.

Figure 7 illustrates one embodiment of a feedback format for group-based cluster allocation.

Figure 8 illustrates frequency reuse and interference in a multi-cell, multi-sector network.

Figure 9 illustrates different cluster formats for coherence clusters and diversity clusters.

Figure 10 illustrates diversity clusters with subcarrier hopping.

Figure 11 illustrates intelligent switching between diversity clusters and coherence clusters depending on subscribers mobility.

Figure 12 illustrates one embodiment of a reconfiguration of cluster classification.

Figure 13 illustrates one embodiment of a base station.

DETAILED DESCRIPTION OF THE PRESENT INVENTION

A distributed, reduced-complexity approach for subcarrier allocation is described. The techniques disclosed herein are described using OFDMA (clusters) as an example. However, they are not limited to OFDMA-based systems. The techniques apply to multi-carrier systems in general, where, for example, a carrier can be a cluster in OFDMA, a spreading code in CDMA, an antenna beam in SDMA (space-division multiple access), etc. In one embodiment, subcarrier allocation is performed in each cell separately. Within each cell, the allocation for individual subscribers (e.g., mobiles) is also made progressively as each new subscriber is added to the system as opposed to joint allocation for subscribers within each cell in which allocation decisions are made taking into account all subscribers in a cell for each allocation.

For downlink channels, each subscriber first measures the channel and interference information for all the subcarriers and then selects multiple subcarriers with good performance (e.g., a high signal-to-interference plus noise ratio (SINR)) and feeds back the information on these candidate subcarriers to the base station. The feedback may comprise channel and interference information (e.g., signal-to-interference-plus-noise-ratio information) on all subcarriers or just a portion of subcarriers. In case of providing information on only a portion of the subcarriers, a subscriber may provide a list of subcarriers ordered starting with those subcarriers which the subscriber desires to use, usually because their performance is good or better than that of other subcarriers.

Upon receiving the information from the subscriber, the base station further selects the subcarriers among the candidates, utilizing additional information available at the base station, e.g., the traffic load information on each subcarrier, amount of traffic requests queued at the base station for each frequency band, whether frequency bands are overused, and/or how long a subscriber has been waiting to send information. In one embodiment, the subcarrier loading information of neighboring cells can also be exchanged between base stations. The base stations can use this information in subcarrier allocation to reduce inter-cell interference.

In one embodiment, the selection by the base station of the channels to allocate, based on the feedback, results in the selection of coding/modulation rates. Such coding/modulation rates may be specified by the subscriber when specifying subcarriers that it finds favorable to use. For example, if the SINR is less than a certain threshold (e.g., 12 dB), quadrature phase shift keying (QPSK) modulation is used; otherwise, 16 quadrature amplitude modulation (QAM) is used. Then the base station informs the subscribers about the subcarrier allocation and the coding/modulation rates to use.

In one embodiment, the feedback information for downlink subcarrier allocation is transmitted to the base station through the uplink access channel, which occurs in a short period every transmission time slot, e.g., 400 microseconds in every 10-millisecond time slot. In one embodiment, the access channel occupies the entire frequency bandwidth. Then the base station can collect the uplink SINR of each subcarrier directly from the access channel. The SINR as well as the traffic load information on the uplink subcarriers are used for uplink subcarrier allocation.

For either direction, the base station makes the final decision of subcarrier allocation for each subscriber.

In the following description, a procedure of selective subcarrier allocation is also disclosed, including methods of channel and interference sensing, methods of information feedback from the subscribers to the base station, and algorithms used by the base station for subcarrier selections.

In the following description, numerous details are set forth to provide a thorough understanding of the present invention. It will be apparent, however, to one skilled in the art, that the present invention may be practiced without these specific details. In other instances, well-known structures and devices are shown in block diagram form, rather than in detail, in order to avoid obscuring the present invention.

Some portions of the detailed descriptions which follow are presented in terms of algorithms and symbolic representations of operations on data bits within a computer memory. These algorithmic descriptions and representations are the means used by those skilled in the data processing arts to most effectively convey the substance of their work to others skilled in the art. An algorithm is here, and generally, conceived to be a self-consistent sequence of steps leading to a desired result. The steps are those requiring physical manipulations of physical quantities. Usually, though not necessarily, these quantities take the form of electrical or magnetic signals capable of being stored, transferred, combined, compared, and otherwise manipulated. It has proven convenient at times, principally for reasons of common usage, to refer to these signals as bits, values, elements, symbols, characters, terms, numbers, or the like.

It should be borne in mind, however, that all of these and similar terms are to be associated with the appropriate physical quantities and are merely convenient labels applied to these quantities. Unless specifically stated otherwise as apparent from the following discussion, it is appreciated that throughout the description, discussions utilizing terms such as "processing" or "computing" or "calculating" or "determining" or "displaying" or the like, refer to the action and processes of a computer system, or similar electronic computing device, that manipulates and transforms data represented as physical (electronic) quantities within the computer system's registers and memories into other data similarly represented as physical quantities within the computer system memories or registers or other such information storage, transmission or display devices.

The present invention also relates to apparatus for performing the operations herein. This apparatus may be specially constructed for the required purposes, or it may comprise a general purpose computer selectively activated or reconfigured by a computer

program stored in the computer. Such a computer program may be stored in a computer readable storage medium, such as, but is not limited to, any type of disk including floppy disks, optical disks, CD-ROMs, and magnetic-optical disks, read-only memories (ROMs), random access memories (RAMs), EPROMs, EEPROMs, magnetic or optical cards, or any type of media suitable for storing electronic instructions, and each coupled to a computer system bus.

The algorithms and displays presented herein are not inherently related to any particular computer or other apparatus. Various general purpose systems may be used with programs in accordance with the teachings herein, or it may prove convenient to construct more specialized apparatus to perform the required method steps. The required structure for a variety of these systems will appear from the description below. In addition, the present invention is not described with reference to any particular programming language. It will be appreciated that a variety of programming languages may be used to implement the teachings of the invention as described herein.

A machine-readable medium includes any mechanism for storing or transmitting information in a form readable by a machine (e.g., a computer). For example, a machine-readable medium includes read only memory ("ROM"); random access memory ("RAM"); magnetic disk storage media; optical storage media; flash memory devices; electrical, optical, acoustical or other form of propagated signals (e.g., carrier waves, infrared signals, digital signals, etc.); etc.

Subcarrier Clustering

The techniques described herein are directed to subcarrier allocation for data traffic channels. In a cellular system, there are typically other channels, pre-allocated for the exchange of control information and other purposes. These channels often include down link and up link control channels, uplink access channels, and time and frequency synchronization channels.

Figure 1A illustrates multiple subcarriers, such as subcarrier 101, and cluster 102. A cluster, such as cluster 102, is defined as a logical unit that contains at least one physical subcarrier, as shown in Figure 1A. A cluster can contain consecutive or disjoint subcarriers. The mapping between a cluster and its subcarriers can be fixed or reconfigurable. In the latter case, the base station informs the subscribers when the clusters are redefined. In one embodiment, the frequency spectrum includes 512

subcarriers and each cluster includes four consecutive subcarriers, thereby resulting in 128 clusters.

An Exemplary Subcarrier/Cluster Allocation Procedure

Figure 1B is a flow diagram of one embodiment of a process for allocation clusters to subscribers. The process is performed by processing logic that may comprise hardware (e.g., dedicated logic, circuitry, etc.), software (such as that which runs on, for example, a general purpose computer system or dedicated machine), or a combination of both.

Referring to Figure 1B, each base station periodically broadcasts pilot OFDM symbols to every subscriber within its cell (or sector) (processing block 101). The pilot symbols, often referred to as a sounding sequence or signal, are known to both the base station and the subscribers. In one embodiment, each pilot symbol covers the entire OFDM frequency bandwidth. The pilot symbols may be different for different cells (or sectors). The pilot symbols can serve multiple purposes: time and frequency synchronization, channel estimation and signal-to-interference/noise (SINR) ratio measurement for cluster allocation.

Next, each subscriber continuously monitors the reception of the pilot symbols and measures the SINR and/or other parameters, including inter-cell interference and intra-cell traffic, of each cluster (processing block 102). Based on this information, each subscriber selects one or more clusters with good performance (e.g., high SINR and low traffic loading) relative to each other and feeds back the information on these candidate clusters to the base station through predefined uplink access channels (processing block 103). For example, SINR values higher than 10 dB may indicate good performance. Likewise, a cluster utilization factor less than 50% may be indicative of good performance. Each subscriber selects the clusters with relatively better performance than others. The selection results in each subscriber selecting clusters they would prefer to use based on the measured parameters.

In one embodiment, each subscriber measures the SINR of each subcarrier cluster and reports these SINR measurements to their base station through an access channel. The SINR value may comprise the average of the SINR values of each of the subcarriers in the cluster. Alternatively, the SINR value for the cluster may be the worst SINR among the SINR values of the subcarriers in the cluster. In still another embodiment, a

weighted averaging of SINR values of the subcarriers in the cluster is used to generate an SINR value for the cluster. This may be particularly useful in diversity clusters where the weighting applied to the subcarriers may be different.

The feedback of information from each subscriber to the base station contains a SINR value for each cluster and also indicates the coding/modulation rate that the subscriber desires to use. No cluster index is needed to indicate which SINR value in the feedback corresponds to which cluster as long as the order of information in the feedback is known to the base station. In an alternative embodiment, the information in the feedback is ordered according to which clusters have the best performance relative to each other for the subscriber. In such a case, an index is needed to indicate to which cluster the accompanying SINR value corresponds.

Upon receiving the feedback from a subscriber, the base station further selects one or more clusters for the subscriber among the candidates (processing block 104). The base station may utilize additional information available at the base station, e.g., the traffic load information on each subcarrier, amount of traffic requests queued at the base station for each frequency band, whether frequency bands are overused, and how long a subscriber has been waiting to send information. The subcarrier loading information of neighboring cells can also be exchanged between base stations. The base stations can use this information in subcarrier allocation to reduce inter-cell interference.

After cluster selection, the base station notifies the subscriber about the cluster allocation through a downlink common control channel or through a dedicated downlink traffic channel if the connection to the subscriber has already been established (processing block 105). In one embodiment, the base station also informs the subscriber about the appropriate modulation/coding rates.

Once the basic communication link is established, each subscriber can continue to send the feedback to the base station using a dedicated traffic channel (e.g., one or more predefined uplink access channels).

In one embodiment, the base station allocates all the clusters to be used by a subscriber at once. In an alternative embodiment, the base station first allocates multiple clusters, referred to herein as the basic clusters, to establish a data link between the base station and the subscriber. The base station then subsequently allocates more clusters, referred to herein as the auxiliary clusters, to the subscriber to increase the communication bandwidth. Higher priorities can be given to the assignment of basic

clusters and lower priorities may be given to that of auxiliary clusters. For example, the base station first ensures the assignment of the basic clusters to the subscribers and then tries to satisfy further requests on the auxiliary clusters from the subscribers. Alternatively, the base station may assign auxiliary clusters to one or more subscribers before allocating basic clusters to other subscribers. For example, a base station may allocate basic and auxiliary clusters to one subscriber before allocating any clusters to other subscribers. In one embodiment, the base station allocates basic clusters to a new subscriber and then determines if there are any other subscribers requesting clusters. If not, then the base station allocates the auxiliary clusters to that new subscriber.

From time to time, processing logic performs retraining by repeating the process described above (processing block 106). The retraining may be performed periodically. This retraining compensates for subscriber movement and any changes in interference. In one embodiment, each subscriber reports to the base station its updated selection of clusters and their associated SINRs. Then the base station further performs the reselection and informs the subscriber about the new cluster allocation. Retraining can be initiated by the base station, and in which case, the base station requests a specific subscriber to report its updated cluster selection. Retraining can also be initiated by the subscriber when it observes channel deterioration.

Adaptive Modulation and Coding

In one embodiment, different modulation and coding rates are used to support reliable transmission over channels with different SINR. Signal spreading over multiple subcarriers may also be used to improve the reliability at very low SINR.

An example coding/modulation table is given below in Table 1.

Table 1

Scheme	Modulation	Code Rate
0	QPSK,1/8 Spreading	½
1	QPSK,¼ Spreading	½
2	QPSK,½ Spreading	½
3	QPSK	½
4	8PSK	2/3
5	16QAM	3/4
6	64QAM	5/6

In the example above, 1/8 spreading indicates that one QPSK modulation symbol is repeated over eight subcarriers. The repetition/spreading may also be extended to the time domain. For example, one QPSK symbol can be repeated over four subcarriers of two OFDM symbols, resulting also 1/8 spreading.

The coding/modulation rate can be adaptively changed according to the channel conditions observed at the receiver after the initial cluster allocation and rate selection.

Pilot Symbols and SINR Measurement

In one embodiment, each base station transmits pilot symbols simultaneously, and each pilot symbol occupies the entire OFDM frequency bandwidth, as shown in Figures 2A-C. Referring to Figure 2A-C, pilot symbols 201 are shown traversing the entire OFDM frequency bandwidth for cells A, B and C, respectively. In one embodiment, each of the pilot symbols have a length or duration of 128 microseconds with a guard time, the combination of which is approximately 152 microseconds. After each pilot period, there are a predetermined number of data periods followed by another set of pilot symbols. In one embodiment, there are four data periods used to transmit data after each pilot, and each of the data periods is 152 microseconds.

A subscriber estimates the SINR for each cluster from the pilot symbols. In one embodiment, the subscriber first estimates the channel response, including the amplitude and phase, as if there is no interference or noise. Once the channel is estimated, the subscriber calculates the interference/noise from the received signal.

The estimated SINR values may be ordered from largest to smallest SINRs and the clusters with large SINR values are selected. In one embodiment, the selected

clusters have SINR values that are larger than the minimum SINR which still allows a reliable (albeit low-rate) transmission supported by the system. The number of clusters selected may depend on the feedback bandwidth and the request transmission rate. In one embodiment, the subscriber always tries to send the information about as many clusters as possible from which the base station chooses.

The estimated SINR values are also used to choose the appropriate coding/modulation rate for each cluster as discussed above. By using an appropriate SINR indexing scheme, an SINR index may also indicate a particular coding and modulation rate that a subscriber desires to use. Note that even for the same subscribers, different clusters can have different modulation/coding rates.

Pilot symbols serve an additional purpose in determining interference among the cells. Since the pilots of multiple cells are broadcast at the same time, they will interfere with each other (because they occupy the entire frequency band). This collision of pilot symbols may be used to determine the amount of interference as a worst case scenario. Therefore, in one embodiment, the above SINR estimation using this method is conservative in that the measured interference level is the worst-case scenario, assuming that all the interference sources are on. Thus, the structure of pilot symbols is such that it occupies the entire frequency band and causes collisions among different cells for use in detecting the worst case SINR in packet transmission systems.

During data traffic periods, the subscribers can determine the level of interference again. The data traffic periods are used to estimate the intra-cell traffic as well as the inter-cell interference level. Specifically, the power difference during the pilot and traffic periods may be used to sense the (intra-cell) traffic loading and inter-cell interference to select the desirable clusters.

The interference level on certain clusters may be lower, because these clusters may be unused in the neighboring cells. For example, in cell A, with respect to cluster A there is less interference because cluster A is unused in cell B (while it is used in cell C). Similarly, in cell A, cluster B will experience lower interference from cell B because cluster B is used in cell B but not in cell C.

The modulation/coding rate based on this estimation is robust to frequent interference changes resulted from bursty packet transmission. This is because the rate prediction is based on the worst case situation in which all interference sources are transmitting.

In one embodiment, a subscriber utilizes the information available from both the pilot symbol periods and the data traffic periods to analyze the presence of both the intra-cell traffic load and inter-cell interference. The goal of the subscriber is to provide an indication to the base station as to those clusters that the subscriber desires to use. Ideally, the result of the selection by the subscriber is clusters with high channel gain, low interference from other cells, and high availability. The subscriber provides feedback information that includes the results, listing desired clusters in order or not as described herein.

Figure 3 illustrates one embodiment of subscriber processing. The processing is performed by processing logic that may comprise hardware (e.g., dedicated logic, circuitry, etc.), software (such as that which runs on, for example, a general purpose computer system or dedicated machine), or a combination of both.

Referring to Figure 3, channel/interference estimation processing block 301 performs channel and interference estimation in pilot periods in response to pilot symbols. Traffic/interference analysis processing block 302 performs traffic and interference analysis in data periods in response to signal information and information from channel/interference estimation block 301.

Cluster ordering and rate prediction processing block 303 is coupled to outputs of channel/interference estimation processing block 301 and traffic/interference analysis processing block 302 to perform cluster ordering and selection along with rate prediction.

The output of cluster ordering processing block 303 is input to cluster request processing block 304, which requests clusters and modulation/coding rates. Indications of these selections are sent to the base station. In one embodiment, the SINR on each cluster is reported to the base station through an access channel. The information is used for cluster selection to avoid clusters with heavy intra-cell traffic loading and/or strong interference from other cells. That is, a new subscriber may not be allocated use of a particular cluster if heavy intra-cell traffic loading already exists with respect to that cluster. Also, clusters may not be allocated if the interference is so strong that the SINR only allows for low-rate transmission or no reliable transmission at all.

The channel/interference estimation by processing block 301 is well-known in the art by monitoring the interference that is generated due to full-bandwidth pilot symbols being simultaneously broadcast in multiple cells. The interface information is

forwarded to processing block 302 which uses the information to solve the following equation:

$$H_i S_i + I_i + n_i = y_i$$

where S_i represents the signal for subcarrier (freq. band) i, I_i is the interference for subcarrier i, n_i is the noise associated with subcarrier i, and y_i is the observation for subcarrier i. In the case of 512 subcarriers, i may range from 0 to 511. The I_i and n_i are not separated and may be considered one quantity. The interference/noise and channel gain H_i are not know. During pilot periods, the signal S_i representing the pilot symbols, and the observation y_i are knowns, thereby allowing determination of the channel gain H_i for the case where there is no interference or noise. Once this is known, it may be plugged back into the equation to determine the interference/noise during data periods since H_i, S_i and y_i are all known.

The interference information from processing blocks 301 and 302 are used by the subscriber to select desirable clusters. In one embodiment, using processing block 303, the subscriber orders clusters and also predicts the data rate that would be available using such clusters. The predicted data rate information may be obtained from a look up table with precalculated data rate values. Such a look up table may store the pairs of each SINR and its associated desirable transmission rate. Based on this information, the subscriber selects clusters that it desires to use based on predetermined performance criteria. Using the ordered list of clusters, the subscriber requests the desired clusters along with coding and modulation rates known to the subscriber to achieve desired data rates.

Figure 4 is one embodiment of an apparatus for the selection of clusters based on power difference. The approach uses information available during both pilot symbol periods and data traffic periods to perform energy detection. The processing of Figure 4 may be implemented in hardware, (e.g., dedicated logic, circuitry, etc.), software (such as is run on, for example, a general purpose computer system or dedicated machine), or a combination of both.

Referring to Figure 4, a subscriber includes SINR estimation processing block 401 to perform SINR estimation for each cluster in pilot periods, power calculation processing block 402 to perform power calculations for each cluster in pilot periods, and

power calculation processing block 403 to perform power calculations in data periods for each cluster. Subtractor 404 subtracts the power calculations for data periods from processing block 403 from those in pilot periods from processing block 402. The output of subtractor 404 is input to power difference ordering (and group selection) processing block 405 that performs cluster ordering and selection based on SINR and the power difference between pilot periods and data periods. Once the clusters have been selected, the subscriber requests the selected clusters and the coding/modulation rates with processing block 406.

More specifically, in one embodiment, the signal power of each cluster during the pilot periods is compared with that during the traffic periods, according to the following:

$$P_P = P_S + P_I + P_N,$$

$$P_D = \begin{cases} P_N\text{, with no signal and interference} \\ P_S + P_N\text{, with signal only} \\ P_I + P_N\text{, with interference only} \\ P_S + P_I + P_N\text{, with both signal and interference} \end{cases}$$

$$P_P - P_D = \begin{cases} P_S + P_I\text{, with no signal and interference} \\ P_I\text{, with signal only} \\ P_S\text{, with interference only} \\ 0\text{, with both signal and interference} \end{cases}$$

where P_P is the measured power corresponding to each cluster during pilot periods, P_D is the measured power during the traffic periods, P_S is the signal power, P_I is the interference power, and P_N is the noise power.

In one embodiment, the subscriber selects clusters with relatively large $P_p/(P_P - P_D)$ (e.g., larger than a threshold such as 10dB) and avoids clusters with low $P_p/(P_P - P_D)$ (e.g., lower than a threshold such as 10dB) when possible.

Alternatively, the difference may be based on the energy difference between observed samples during the pilot period and during the data traffic period for each of the subcarriers in a cluster such as the following:

$$\Delta_i = \left|y_i^P\right| - \left|y_i^D\right|$$

Thus, the subscriber sums the differences for all subcarriers.

Depending on the actual implementation, a subscriber may use the following metric, a combined function of both SINR and $P_P - P_D$, to select the clusters:

$$\beta = f(\text{SINR}, P_P /(P_P - P_D)$$

where f is a function of the two inputs. One example of f is weighted averaging (e.g., equal weights). Alternatively, a subscriber selects a cluster based on its SINR and only uses the power difference $P_P - P_D$ to distinguish clusters with similar SINR. The difference may be smaller than a threshold (e.g., 1 dB).

Both the measurement of SINR and $P_P - P_D$ can be averaged over time to reduce variance and improve accuracy. In one embodiment, a moving-average time window is used that is long enough to average out the statistical abnormity yet short enough to capture the time-varying nature of channel and interference, e.g., 1 millisecond.

Feedback Format for Downlink Cluster Allocation

In one embodiment, for the downlink, the feedback contains both the indices of selected clusters and their SINR. An exemplary format for arbitrary cluster feedback is shown in Figure 5. Referring to Figure 5, the subscriber provides a cluster index (ID) to indicate the cluster and its associated SINR value. For example, in the feedback, the subscriber provides cluster ID1 (501) and the SINR for the cluster, SINR1 (502), cluster ID2 (503) and the SINR for the cluster, SINR2 (504), and cluster ID3 (505), and the SINR for the cluster, SINR3 (506), etc. The SINR for the cluster may be created using an average of the SINRs of the subcarriers. Thus, multiple arbitrary clusters can be selected as the candidates. As discussed above, the selected clusters can also be ordered in the feedback to indicate priority. In one embodiment, the subscriber may form a priority list of clusters and sends back the SINR information in a descending order of priority.

Typically, an index to the SINR level, instead of the SINR itself is sufficient to indicate the appropriate coding/modulation for the cluster. For example, a 3-bit field can be used for SINR indexing to indicate 8 different rates of adaptive coding/modulation.

An Exemplary Base Station

The base station assigns desirable clusters to the subscriber making the request. In one embodiment, the availability of the cluster for allocation to a subscriber depends on the total traffic load on the cluster. Therefore, the base station selects the clusters not only with high SINR, but also with low traffic load.

Figure 13 is a block diagram of one embodiment of a base station. Referring to Figure 13, cluster allocation and load scheduling controller 1301 (cluster allocator) collects all the necessary information, including the downlink/uplink SINR of clusters specified for each subscriber (e.g., via SINR/rate indices signals 1313 received from OFDM transceiver 1305) and user data, queue fullness/traffic load (e.g., via user data buffer information 1311 from multi-user data buffer 1302). Using this information, controller 1301 makes the decision on cluster allocation and load scheduling for each user, and stores the decision information in a memory (not shown). Controller 1301 informs the subscribers about the decisions through control signal channels (e.g., control signal/cluster allocation 1312 via OFDM transceiver 1305). Controller 1301 updates the decisions during retraining.

In one embodiment, controller 1301 also performs admission control to user access since it knows the traffic load of the system. This may be performed by controlling user data buffers 1302 using admission control signals 1310.

The packet data of User 1 ~ N are stored in the user data buffers 1302. For downlink, with the control of controller 1301, multiplexer 1303 loads the user data to cluster data buffers (for Cluster 1 ~ M) waiting to be transmitted. For the uplink, multiplexer 1303 sends the data in the cluster buffers to the corresponding user buffers. Cluster buffer 1304 stores the signal to be transmitted through OFDM transceiver 1305 (for downlink) and the signal received from transceiver 1305. In one embodiment, each user might occupy multiple clusters and each cluster might be shared by multiple users (in a time-division-multiplexing fashion).

Group-Based Cluster Allocation

In another embodiment, for the downlink, the clusters are partitioned into groups. Each group can include multiple clusters. Figure 6 illustrates an exemplary partitioning. Referring to Figure 6, groups 1-4 are shown with arrows pointing to clusters that are in each group as a result of the partitioning. In one embodiment, the clusters within each group are spaced far apart over the entire bandwidth. In one embodiment, the clusters

within each group are spaced apart farther than the channel coherence bandwidth, i.e. the bandwidth within which the channel response remains roughly the same. A typical value of coherence bandwidth is 100 kHz for many cellular systems. This improves frequency diversity within each group and increases the probability that at least some of the clusters within a group can provide high SINR. The clusters may be allocated in groups. Goals of group-based cluster allocation include reducing the data bits for cluster indexing, thereby reducing the bandwidth requirements of the feedback channel (information) and control channel (information) for cluster allocation. Group-based cluster allocation may also be used to reduce inter-cell interference.

After receiving the pilot signal from the base station, a subscriber sends back the channel information on one or more cluster groups, simultaneously or sequentially. In one embodiment, only the information on some of the groups is sent back to the base station. Many criteria can be used to choose and order the groups, based on the channel information, the inter-cell interference levels, and the intra-cell traffic load on each cluster.

In one embodiment, a subscriber first selects the group with the best overall performance and then feedbacks the SINR information for the clusters in that group. The subscriber may order the groups based on their number of clusters for which the SINR is higher than a predefined threshold. By transmitting the SINR of all the clusters in the group sequentially, only the group index, instead of all the cluster indices, needs to be transmitted. Thus, the feedback for each group generally contains two types of information: the group index and the SINR value of each cluster within the group. Figure 7 illustrates an exemplary format for indicating a group-based cluster allocation. Referring to Figure 7, a group ID, ID1, is followed by the SINR values for each of the clusters in the group. This can significantly reduce the feedback overhead.

Upon receiving the feedback information from the subscriber, the cluster allocator at the base station selects multiple clusters from one or more groups, if available, and then assigns the clusters to the subscriber. This selection may be performed by an allocation in a media access control portion of the base station.

Furthermore, in a multi-cell environment, groups can have different priorities associated with different cells. In one embodiment, the subscriber's selection of a group is biased by the group priority, which means that certain subscribers have higher priorities on the usage of some groups than the other subscribers.

In one embodiment, there is no fixed association between one subscriber and one cluster group; however, in an alternative embodiment there may be such a fixed association. In an implementation having a fixed association between a subscriber and one or more cluster groups, the group index in the feedback information can be omitted, because this information is known to both subscriber and base station by default.

In another embodiment, the pilot signal sent from the base station to the subscriber also indicates the availability of each cluster, e.g., the pilot signal shows which clusters have already been allocated for other subscribers and which clusters are available for new allocations. For example, the base station can transmit a pilot sequence 1111 1111 on the subcarriers of a cluster to indicate that the cluster is available, and 1111 –1-1-1-1 to indicate the cluster is not available. At the receiver, the subscriber first distinguishes the two sequences using the signal processing methods which are well known in the art, e.g., the correlation methods, and then estimates the channel and interference level.

With the combination of this information and the channel characteristics obtained by the subscriber, the subscriber can prioritize the groups to achieve both high SINR and good load balancing.

In one embodiment, the subscriber protects the feedback information by using error correcting codes. In one embodiment, the SINR information in the feedback is first compressed using source coding techniques, e.g., differential encoding, and then encoded by the channel codes.

Figure 8 shows one embodiment of a frequency reuse pattern for an exemplary cellular set up. Each cell has hexagonal structure with six sectors using directional antennas at the base stations. Between the cells, the frequency reuse factor is one. Within each cell, the frequency reuse factor is 2 where the sectors use two frequencies alternatively. As shown in Figure 8, each shaded sector uses half of the available OFDMA clusters and each unshaded sector uses the other half of the clusters. Without loss of generality, the clusters used by the shaded sectors are referred to herein as odd clusters and those used by the unshaded sectors are referred to herein as even clusters.

Consider the downlink signaling with omni-directional antennas at the subscribers. From Figure 8, it is clear that for the downlink in the shaded sectors, Cell A interferes with Cell B, which in turn interferes with Cell C, which in turn interferes with Cell A, namely, A -> B -> C ->A. For the unshaded sectors, Cell A interferes with Cell

C, which in turn interferes with Cell B, which in turn interferes with Cell A, namely, A -> C -> B ->A.

Sector A1 receives interference from Sector C1, but its transmission interferes with Sector B1. Namely, its interference source and the victims with which it interferes are not the same. This might cause a stability problem in a distributed cluster-allocation system using interference avoidance: if a frequency cluster is assigned in Sector B1 but not in Sector C1, the cluster may be assigned in A1 because it may be seen as clean in A1. However, the assignment of this cluster A1 can cause interference problem to the existing assignment in B1.

In one embodiment, different cluster groups are assigned different priorities for use in different cells to alleviate the aforementioned problem when the traffic load is progressively added to a sector. The priority orders are jointly designed such that a cluster can be selectively assigned to avoid interference from its interference source, while reducing, and potentially minimizing, the probability of causing interference problem to existing assignments in other cells.

Using the aforementioned example, the odd clusters (used by the shaded sectors) are partitioned into 3 groups: Group 1, 2, 3. The priority orders are listed in Table 2.

Table 2: Priority ordering for the downlink of the shaded sectors.

Priority Ordering	Cell A	Cell B	Cell C
1	Group 1	Group 3	Group 2
2	Group 2	Group 1	Group 3
3	Group 3	Group 2	Group 1

Consider Sector A1. First, the clusters in Group 1 are selectively assigned. If there are still more subscribers demanding clusters, the clusters in Group 2 are selectively assigned to subscribers, depending on the measured SINR (avoiding the clusters receiving strong interference from Sector C1). Note that the newly assigned clusters from Group 2 to Sector A1 shall not cause interference problem in Sector B1, unless the load in Sector B1 is so heavy that the clusters in both Group 3 and 1 are used up and the clusters in Group 2 are also used. Table 3 shows the cluster usage when less than 2/3 of all the available clusters are used in Sector A1, B1, and C1.

Table 3: Cluster usage for the downlink of the shaded sectors with less than 2/3 of the full load.

Cluster Usage	Cell A	Cell B	Cell C
1	Group 1	Group 3	Group 2
2	Group 2	Group 1	Group 3
3			

Table 4 shows the priority orders for the unshaded sectors, which are different from those for the shaded sectors, since the interfering relationship is reversed.

Table 4: Priority ordering for the downlink of the unshaded sectors.

Priority Ordering	Cell A	Cell B	Cell C
1	Group 1	Group 2	Group 3
2	Group 2	Group 3	Group 1
3	Group 3	Group 1	Group 2

<u>Intelligent Switching between Coherence and Diversity Clusters</u>

In one embodiment, there are two categories of clusters: coherence clusters, containing multiple subcarriers close to each other and diversity clusters, containing multiple subcarriers with at least some of the subcarriers spread far apart over the spectrum. The closeness of the multiple subcarriers in coherence clusters is preferably within the channel coherence bandwidth, i.e. the bandwidth within which the channel response remains roughly the same, which is typically within 100 kHz for many cellular systems. On the other hand, the spread of subcarriers in diversity clusters is preferably larger than the channel coherence bandwidth, typically within 100 kHz for many cellular systems. Of course, the larger the spread, the better the diversity. Therefore, a general goal in such cases is to maximize the spread.

Figure 9 illustrates exemplary cluster formats for coherence clusters and diversity clusters for Cells A-C. Referring to Figure 9, for cells A-C, the labeling of frequencies (subcarriers) indicates whether the frequencies are part of coherence or diversity clusters. For example, those frequencies labeled 1-8 are diversity clusters and those labeled 9-16 are coherence clusters. For example, all frequencies labeled 1 in a cell are part of one diversity cluster, all frequencies labeled 2 in a cell are part of another diversity cluster, etc., while the group of frequencies labeled 9 are one coherence cluster, the group of

frequencies labeled 10 are another coherence cluster, etc. The diversity clusters can be configured differently for different cells to reduce the effect of inter-cell interference through interference averaging.

Figure 9 shows example cluster configurations for three neighboring cells. The interference from a particular cluster in one cell are distributed to many clusters in other cells, e.g., the interference from Cluster 1 in Cell A are distributed to Cluster 1, 8, 7, 6 in Cell B. This significantly reduces the interference power to any particular cluster in Cell B. Likewise, the interference to any particular cluster in one cell comes from many different clusters in other cells. Since not all cluster are strong interferers, diversity clusters, with channel coding across its subcarriers, provide interference diversity gain. Therefore, it is advantageous to assign diversity clusters to subscribers that are close (e.g., within the coherent bandwidth) to the cell boundaries and are more subject to inter-cell interference.

Since the subcarriers in a coherence cluster are consecutive or close (e.g., within the coherent bandwidth) to each other, they are likely within the coherent bandwidth of the channel fading. Therefore, the channel gain of a coherence cluster can vary significantly and cluster selection can greatly improve the performance. On the other hand, the average channel gain of a diversity cluster has less of a degree of variation due to the inherent frequency diversity among the multiple subcarriers spread over the spectrum. With channel coding across the subcarriers within the cluster, diversity clusters are more robust to cluster mis-selection (by the nature of diversification itself), while yielding possibly less gain from cluster selection. Channel coding across the subcarriers means that each codeword contains bits transmitted from multiple subcarriers, and more specifically, the difference bits between codewords (error vector) are distributed among multiple subcarriers.

More frequency diversity can be obtained through subcarrier hopping over time in which a subscriber occupies a set of subcarriers at one time slot and another different set of subcarriers at a different time slot. One coding unit (frame) contains multiple such time slots and the transmitted bits are encoded across the entire frame.

Figure 10 illustrates diversity cluster with subcarrier hopping. Referring to Figure 10, there are four diversity clusters in each of cells A and B shown, with each subcarrier in individual diversity clusters having the same label (1, 2, 3, or 4). There are four separate time slots shown and during each of the time slots, the subcarriers for each

of the diversity clusters change. For example, in cell A, subcarrier 1 is part of diversity cluster 1 during time slot 1, is part of diversity cluster 2 during time slot 2, is part of diversity cluster 3 during time slot 3, and is part of diversity cluster 4 during time slot 4. Thus, more interference diversity can be obtained through subcarrier hopping over time, with further interference diversity achieved by using different hopping patterns for different cells, as shown in Figure 10.

The manner in which the subscriber changes the subcarriers (hopping sequences) can be different for different cells in order to achieve better interference averaging through coding.

For static subscribers, such as in fixed wireless access, the channels change very little over time. Selective cluster allocation using the coherence clusters achieves good performance. On the other hand, for mobile subscribers, the channel time variance (the variance due to changes in the channel over time) can be very large. A high-gain cluster at one time can be in deep fade at another. Therefore, cluster allocation needs to be updated at a rapid rate, causing significant control overhead. In this case, diversity clusters can be used to provide extra robustness and to alleviate the overhead of frequent cluster reallocation. In one embodiment, cluster allocation is performed faster than the channel changing rate, which is often measured by the channel Doppler rate (in Hz), i.e. how many cycles the channel changes per second where the channel is completely different after one cycle. Note that selective cluster allocation can be performed on both coherence and diversity clusters.

In one embodiment, for cells containing mixed mobile and fixed subscribers, a channel/interference variation detector can be implemented at either the subscriber or the base station, or both. Using the detection results, the subscriber and the base station intelligently selects diversity clusters to mobile subscribers or fixed subscribers at cell boundaries, and coherence clusters to fixed subscribers close to the base station. The channel/interference variation detector measures the channel (SINR) variation from time to time for each cluster. For example, in one embodiment, the channel/interference detector measures the power difference between pilot symbols for each cluster and averages the difference over a moving window (e.g., 4 time slots). A large difference indicates that channel/interference changes frequently and subcarrier allocation may be not reliable. In such a case, diversity clusters are more desirable for the subscriber.

Figure 11 is a flow diagram of one embodiment of a process for intelligent selection between diversity clusters and coherence clusters depending on subscribers mobility. The process is performed by processing logic that may comprise hardware (e.g., circuitry, dedicated logic, etc.), software (such as that which runs on, for example, a general purpose computer system or dedicated machine), or a combination of both.

Referring to Figure 11, processing logic in the base station performs channel/interference variation detection (processing block 1101). Processing logic then tests whether the results of the channel/interference variation detection indicate that the user is mobile or in a fixed position close to the edge of the cell (processing block 1102). If the user is not mobile or is not in a fixed position close to the edge of the cell, processing transitions to processing block 1103 where processing logic in the base station selects coherence clusters; otherwise, processing transitions to processing block 1104 in which processing logic in the base station selects diversity clusters.

The selection can be updated and intelligently switched during retraining.

The ratio/allocation of the numbers of coherence and diversity clusters in a cell depends on the ratio of the population of mobile and fixed subscribers. When the population changes as the system evolves, the allocation of coherence and diversity clusters can be reconfigured to accommodate the new system needs. Figure 12 illustrates a reconfiguration of cluster classification which can support more mobile subscribers than that in Figure 9.

Whereas many alterations and modifications of the present invention will no doubt become apparent to a person of ordinary skill in the art after having read the foregoing description, it is to be understood that any particular embodiment shown and described by way of illustration is in no way intended to be considered limiting. Therefore, references to details of various embodiments are not intended to limit the scope of the claims which in themselves recite only those features regarded as essential to the invention.

CLAIMS

We claim:

1. A method for subcarrier selection for a system employing orthogonal frequency division multiple access (OFDMA) comprising:

a subscriber measuring channel and interference information for a plurality of subcarriers based on pilot symbols received from a base station;

the subscriber selecting a set of candidate subcarriers;

the subscriber providing feedback information on the set of candidate subcarriers to the base station; and

the subscriber receiving an indication of subcarriers of the set of subcarriers selected by the base station for use by the subscriber.

2. The method defined in Claim 1 further comprising the subscriber continuously monitoring reception of the pilot symbols known to the base station and measuring signal-plus-interference-to-noise ratio (SINR) of each cluster of subcarriers.

3. The method defined in Claim 2 further comprising the subscriber measuring inter-cell interference, wherein the subscriber selects candidate subcarriers based on the inter-cell interference.

4. The method defined in Claim 3 further comprising the base station selecting subcarriers for the subscriber based on inter-cell interference avoidance.

5. The method defined in Claim 2 further comprising the subscriber measuring intra-cell traffic, wherein the subscriber selects candidate subcarriers based on the intra-cell traffic load balancing.

6. The method defined in Claim 5 further comprising the base station selecting the subcarriers in order to balance intra-cell traffic load on each cluster.

7. The method defined in Claim 1 further comprising the subscriber submitting new feedback information after being allocated the set of subscribers to be allocated a new set of subcarriers and thereafter the subscriber receiving another indication of the new set of subcarriers.

8. The method defined in Claim 1 further comprising the subscriber using information from pilot symbol periods and data periods to measure channel and interference information.

9. The method defined in Claim 8 wherein the subscriber selects candidate subcarriers based on the SINR of a cluster of subcarriers and a difference between measured power corresponding to each cluster during pilot periods and measured power during data periods.

10. The method defined in Claim 9 further comprising the subscriber using the power difference to distinguish, during selection, clusters of subcarriers having substantially similar SINRs.

11. The method defined in Claim 8 further comprising the subscriber using information from pilot symbol periods and data traffic periods to analyze presence of intra-cell traffic load and inter-cell interference.

12. The method defined in Claim 1 wherein the pilot symbols occupy an entire OFDM frequency bandwidth.

13. The method defined in Claim 12 wherein at least one other pilot symbol from a different cell transmitted at the same time as the pilot symbols received from the base station collide with each other.

14. The method defined in Claim 1 further comprising the base station selecting the subcarriers from the set of candidate subcarriers based on additional information available to the base station.

15. The method defined in Claim 14 wherein the additional information comprises traffic load information on each cluster of subcarriers.

16. The method defined in Claim 15 wherein the traffic load information is provided by a data buffer in the base station.

17. The method defined in Claim 1 wherein the indication of subcarriers is received via a downlink control channel.

18. The method defined in Claim 1 wherein the plurality of subcarriers comprises all subcarriers allocable by a base station.

19. The method defined in Claim 1 wherein providing feedback information comprises arbitrarily ordering the set of candidate of subcarriers as clusters of subcarriers.

20. The method defined in Claim 19 wherein arbitrarily order candidate clusters comprise clusters in an order with most desirable candidate clusters being listed first.

21. The method defined in Claim 19 wherein the feedback information includes an index indication of a candidate cluster with its SINR value.

22. The method defined in Claim 21 wherein each index is indicative of a coding and modulation rate.

23. The method defined in Claim 1 wherein providing feedback information comprises sequentially ordering candidate clusters.

24. The method defined in Claim 1 further comprising the subscriber sending an indication of coding and modulation rates that the subscriber desires to employ for each cluster.

25. The method defined in Claim 24 wherein the indication of coding and modulation rates comprises an SINR index indicative of a coding and modulation rate.

26. The method defined in Claim 1 further comprising:

the base station allocating a first portion of the subcarriers to establish a data link between the base station and the subscriber; and then

the base station allocating a second portion of the subcarriers to the subscriber to increase communication bandwidth.

27. The method defined in Claim 26 wherein the base station allocates the second portion after allocating each subscriber in the cell subcarriers to establish a data link between the base station and said each subscriber.

28. The method defined in Claim 26 wherein, due to subscriber priority, the base station allocates the second portion before allocating each subscriber in the cell subcarriers to establish their data link to the base station.

29. An apparatus comprising:

a plurality of subscribers in a first cell to generate feedback information indicating clusters of subcarriers desired for use by the plurality of subscribers; and

a first base station in the first cell, the first base station performing subcarrier allocation for OFDMA to allocate OFDMA subcarriers in clusters to the plurality of subscribers based on inter-cell interference avoidance and intra-cell traffic load balancing in response to the feedback information.

30. An apparatus comprising:

a plurality of subscribers in a first cell to generate feedback information indicating clusters of subcarriers desired for use by the plurality of subscribers; and

a first base station in the first cell, the first base station to allocate OFDMA subcarriers in clusters to the plurality of subscribers;

each of a plurality of subscribers to measure channel and interference information for the plurality of subcarriers based on pilot symbols received from the first base station and at least one of the plurality of subscribers to select a set of candidate subcarriers from the plurality of subcarriers, and the one subscriber to provide feedback information on the set of candidate subcarriers to the base station and to receive an indication of subcarriers from the set of subcarriers selected by the first base station for use by the one subscriber.

31. The apparatus defined in Claim 30 wherein each of the plurality of subscribers continuously monitors reception of the pilot symbols known to the base station and the plurality of subscribers and measures signal-plus-interference-to-noise ratio (SINR) of each cluster of subcarriers.

32. The apparatus defined in Claim 31 wherein each of the plurality of subscribers measures inter-cell interference, wherein the at least one subscriber selects candidate subcarriers based on the inter-cell interference.

33. The apparatus defined in Claim 32 wherein the base station selects subcarriers for the one subscriber based on inter-cell interference avoidance.

34. The apparatus defined in Claim 31 wherein each of the plurality of subscribers measures intra-cell traffic, wherein the at least one subscriber selects candidate subcarriers based on the intra-cell traffic load balancing.

35. The apparatus defined in Claim 34 wherein the base station selects subcarriers in order to balance intra-cell traffic load on each cluster of subcarriers.

36. The apparatus defined in Claim 30 wherein the subscriber submits new feedback information after being allocated the set of subscribers to receive a new set of subcarriers and thereafter receives another indication of the new set of subcarriers.

37. The apparatus defined in Claim 30 wherein the at least one subscriber uses information from pilot symbol periods and data periods to measure channel and interference information.

38. The apparatus defined in Claim 30 wherein the at least one subscriber selects candidate subcarriers based on SINR of the cluster and a difference between

measured power corresponding to each cluster during pilot periods and measured power during data periods.

39. The apparatus defined in Claim 38 wherein the one subscriber distinguishes, during selection, cluster of subcarriers having substantially similar SINRs based on the power difference.

40. The apparatus defined in Claim 38 wherein the at least one subscriber uses information from pilot symbol periods and data traffic periods to analyze presence of intra-cell traffic load and inter-cell interference.

41. The apparatus defined in Claim 38 wherein the pilot symbols occupy an entire OFDM frequency bandwidth.

42. The apparatus defined in Claim 41 wherein at least one other pilot symbol from a different cell transmitted at the same time as the pilot symbols received from the base station collide with each other.

43. The apparatus defined in Claim 30 wherein the base station selects the subcarriers from the set of candidate subcarriers based on additional information available to the base station.

44. The apparatus defined in Claim 43 wherein the additional information comprises traffic load information on each cluster of subcarriers.

45. The apparatus defined in Claim 44 wherein the traffic load information is provided by a data buffer in the base station.

46. The apparatus defined in Claim 30 wherein the indication of subcarriers is received via a downlink control channel between the base station and the at least one subscriber.

47. The apparatus defined in Claim 30 wherein the plurality of subcarriers comprises all subcarriers allocable by a base station.

48. The apparatus defined in Claim 30 wherein the plurality of subscribers provide feedback information that comprises an arbitrarily ordered set of candidate subcarriers as clusters of subcarriers.

49. The apparatus defined in Claim 48 wherein arbitrarily order candidate clusters comprise clusters in an order with most desirable candidate clusters being listed first.

50. The apparatus defined in Claim 48 wherein the feedback information includes an index indication of a candidate cluster with it SINR value.

51. The apparatus defined in Claim 50 wherein each index is indicative of a coding and modulation rate.

52. The apparatus defined in Claim 30 wherein providing feedback information comprises sequentially ordering candidate clusters.

53. The apparatus defined in Claim 30 wherein the one subscriber sends an indication of coding and modulation rates that the one subscriber desires to employ.

54. The apparatus defined in Claim 53 wherein the indication of coding and modulation rates comprises an SINR index indicative of a coding and modulation rate.

55. The apparatus defined in Claim 30 wherein the base station allocates a first portion of the subcarriers to establish a data link between the base station and the subscriber; and then allocates a second portion of the subcarriers to the subscriber to increase communication bandwidth.

56. The apparatus defined in Claim 55 wherein the base station allocates the second portion after allocating each subscriber in the cell subcarriers to establish a data link between the base station and said each subscriber.

57. The apparatus defined in Claim 55 wherein, due to subscriber priority, the base station allocates the second portion before allocating each subscriber in the cell subcarriers to establish their data link to the base station.

58. A method comprising:

the base station allocating a first portion of the subcarriers to establish a data link between the base station and the subscriber; and then

the base station allocating a second portion of the subcarriers to the subscriber to increase communication bandwidth.

59. The method defined in Claim 57 wherein the base station allocates the second portion after allocating each subscriber in the cell subcarriers to establish a data link between the base station and said each subscriber.

60. A base station comprising:

means for allocating a first portion of the subcarriers to establish a data link between the base station and the subscriber; and

means for allocating a second portion of the subcarriers to the subscriber to increase communication bandwidth.

61. The apparatus defined in Claim 60 wherein the base station allocates the second portion after allocating each subscriber in the cell subcarriers to establish a data link between the base station and said each subscriber.

62. An apparatus comprising:

a plurality of subscribers in a cell; and

a base station in the cell, the base station to perform subcarrier allocation for OFDMA to allocate OFDMA subcarriers in clusters to the plurality of subscribers based on inter-cell interference avoidance and intra-cell traffic load balancing.

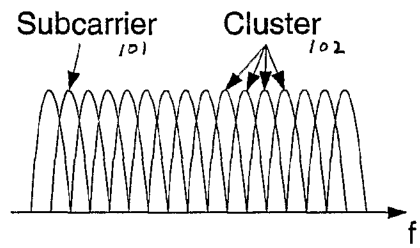


Figure 1A

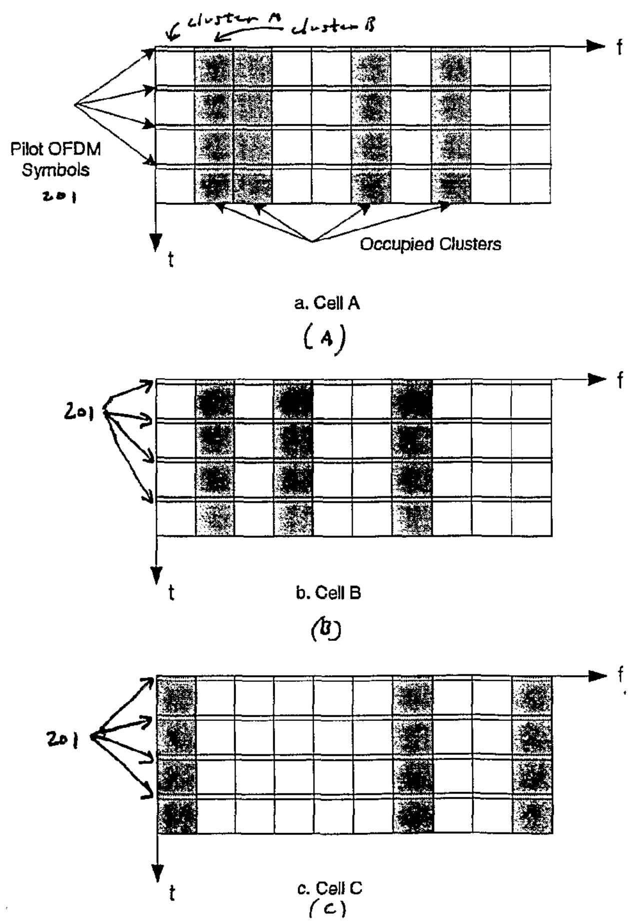


Figure 2

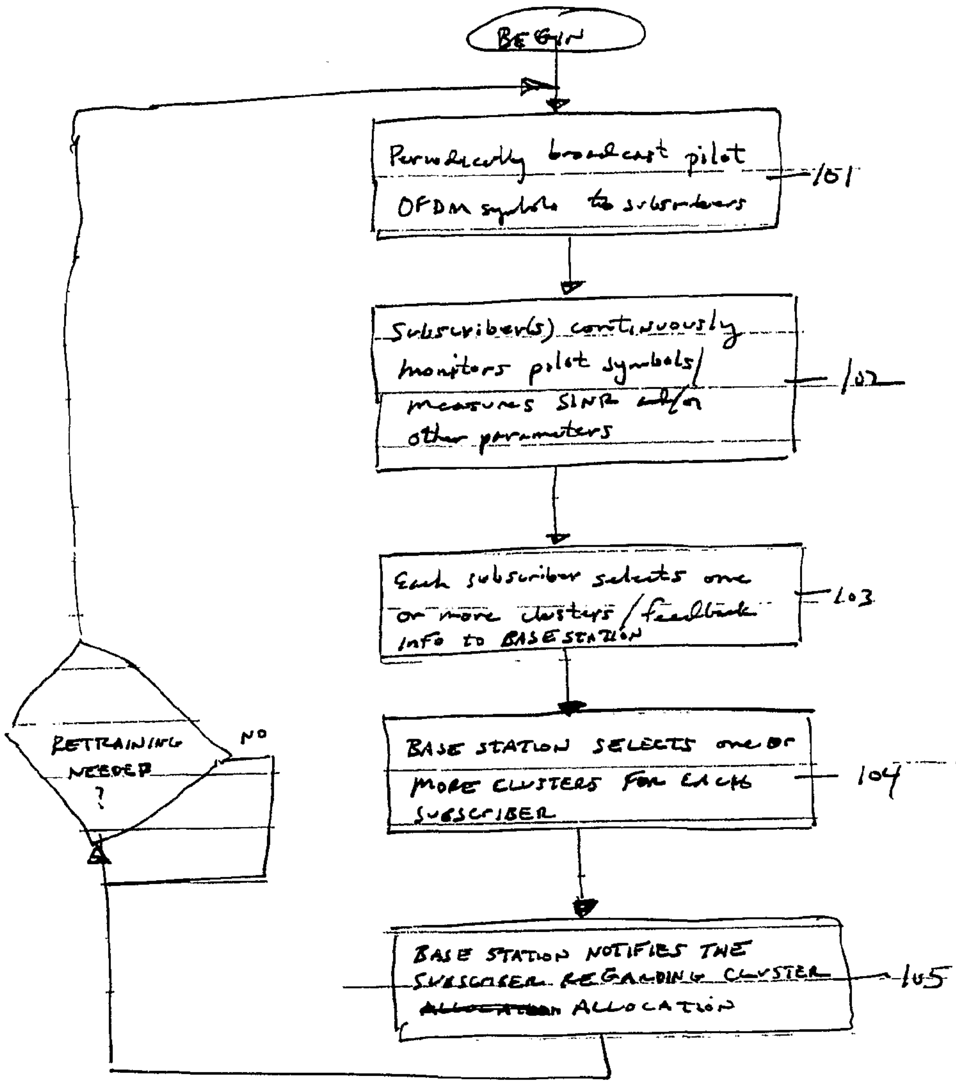

BEGIN
Periodically broadcast pilot OFDM symbols to subscribers
101
Subscriber(s) continuously monitors pilot symbols/ measures SINR and/or other parameters
102
Each subscriber selects one or more clusters/feedback info to BASE STATION
103
BASE STATION SELECTS one or MORE CLUSTERS FOR EACH SUBSCRIBER
104
BASE STATION NOTIFIES THE SUBSCRIBER REGARDING CLUSTER ALLOCATION
105
RETRAINING NEEDED ?
NO

Figure 1B

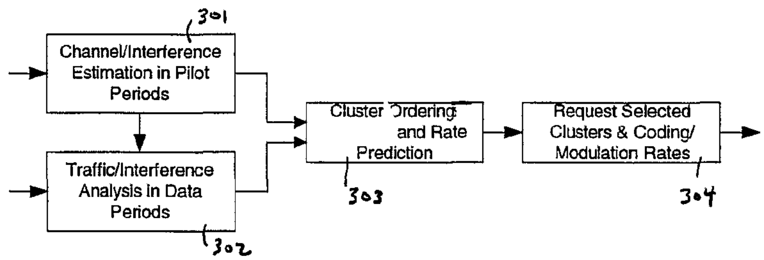


Figure 3.

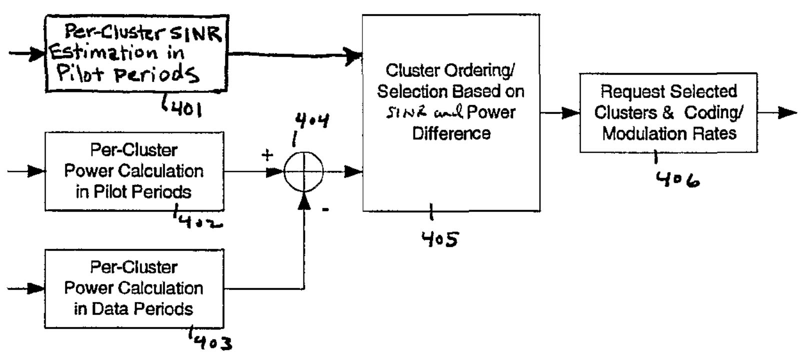


Figure 4

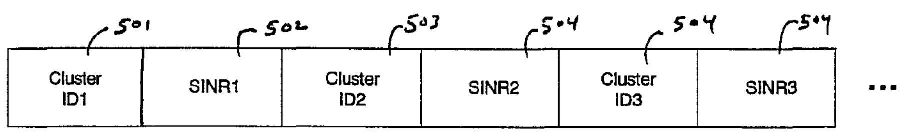


Figure 5

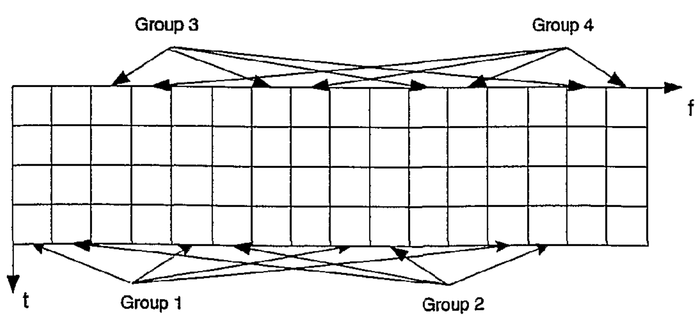


Figure 6

Group ID1	SINR1	SINR2	SINR3	Group ID2	SINR1	SINR2	SINR3

Figure 7

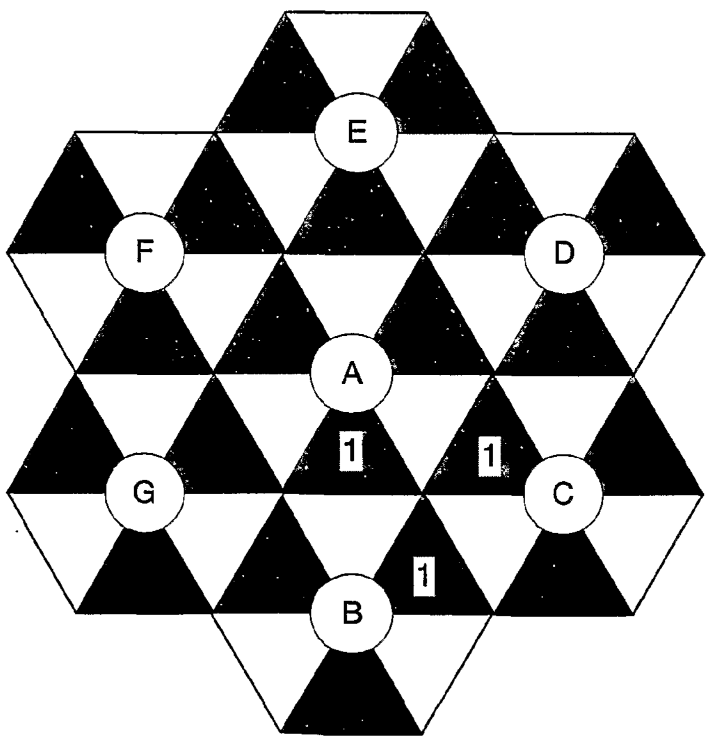


Figure 8

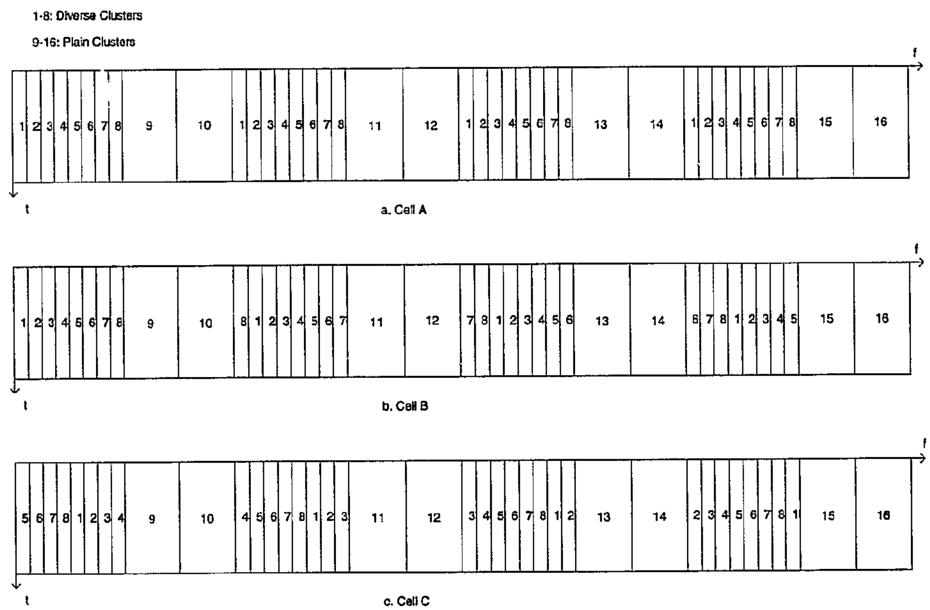


Figure 9

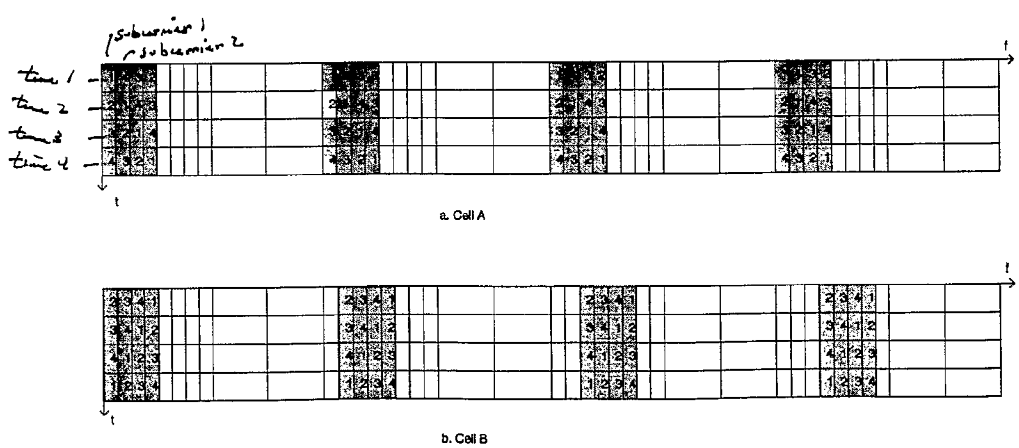


Figure 10

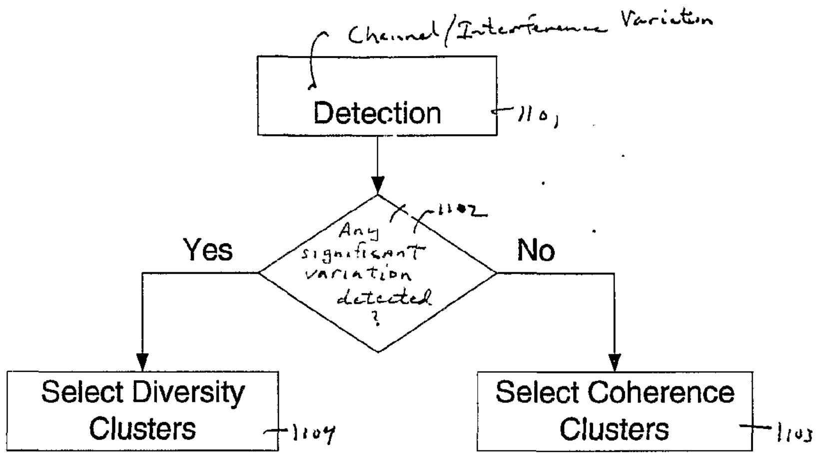


Figure 11

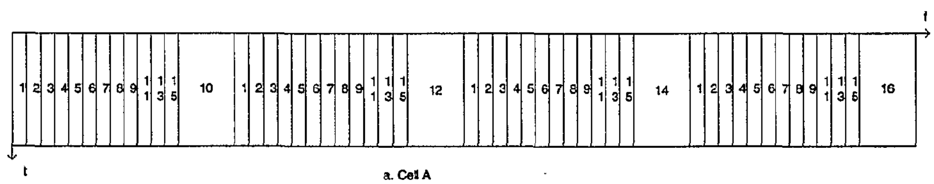
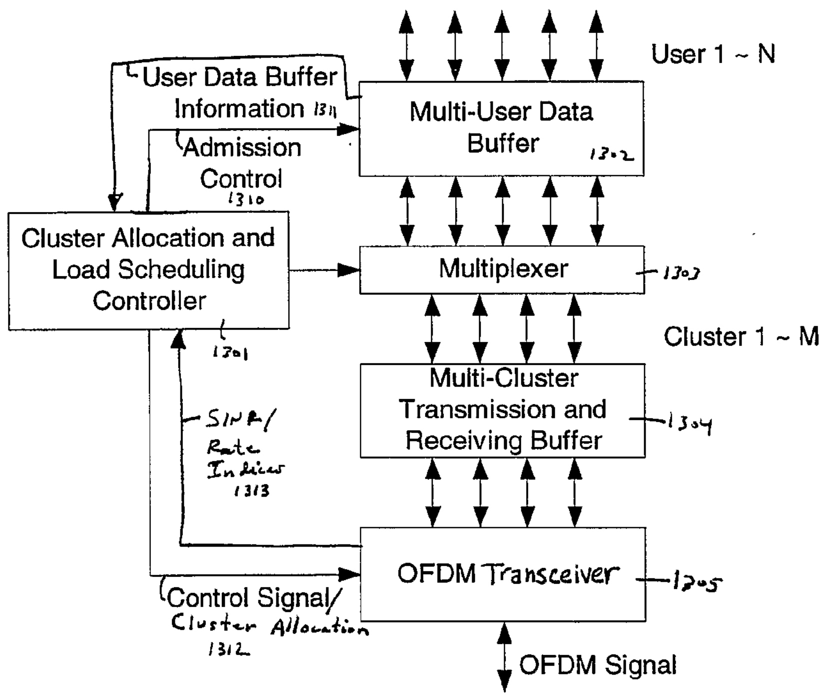


Figure 12



User 1 ~ N
User Data Buffer Information 1311
Multi-User Data Buffer 1302
Admission Control 1310
Cluster Allocation and Load Scheduling Controller
1301
Multiplexer
1303
Cluster 1 ~ M
Multi-Cluster Transmission and Receiving Buffer
1304
SINR/ Rate Indices 1313
OFDM Transceiver
1305
Control Signal/ Cluster Allocation 1312
OFDM Signal

Figure 13

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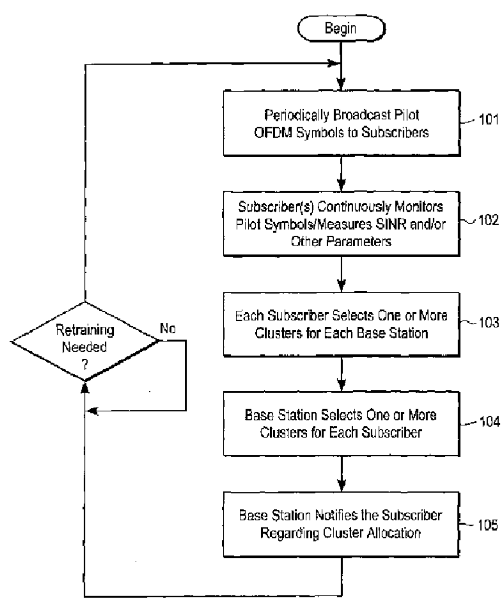
最終頁に続く

(54)【発明の名称】適応サブキャリアークラスタ構成及び選択的ローディングを備えたＯＦＤＭＡ

(57)【要約】
システムのためのサブキャリア選択の方法と装置が開示されている。或る実施形態では、システムは、直交周波数分割多重アクセス（ＯＦＤＭＡ）を採用している。或る実施形態では、サブキャリア選択の方法は、複数の加入者それぞれが、基地局から受信したパイロット記号に基づいてサブキャリアのチャネル及び干渉の情報を測定する段階と、加入者の少なくとも１人が候補サブキャリアのセットを選択する段階と、候補サブキャリアのセットに関するフィードバック情報を基地局に提供する段階と、１人の加入者が基地局に対するサブキャリアの表示を受信する段階と、１人の加入者が、その加入者が使用するように基地局が選択したサブキャリアのセットの内のサブキャリアの表示を受信する段階とから成る。



【特許請求の範囲】
【請求項１】
直交周波数分割多重アクセス（ＯＦＤＭＡ）を採用しているシステムのためのサブキャリア選択の方法において、
加入者が、基地局から受信したパイロット記号に基づいて、複数のサブキャリアについてチャネル及び干渉情報を測定する段階と、
前記加入者が、候補サブキャリアのセットを選択する段階と、
前記加入者が、前記候補サブキャリアのセットに関するフィードバック情報を前記基地局に提供する段階と、
前記加入者が、前記加入者用として前記基地局により選択された前記サブキャリアのセットのサブキャリアの表示を受信する段階と、から成ることを特徴とする方法。
【請求項２】
前記加入者が、前記基地局にとって既知のパイロット記号の受信を継続的にモニターして、サブキャリアの各クラスタの信号対干渉＋ノイズ比（signal-plus-interference-to-noise ratio）（ＳＩＮＲ）を測定する段階を更に含んでいることを特徴とする請求項１に記載の方法。
【請求項３】
前記加入者がセル間干渉を測定する段階を更に含んでおり、前記加入者は、セル間干渉に基づいて候補サブキャリアを選択することを特徴とする請求項２に記載の方法。
【請求項４】
前記基地局が、セル間干渉回避に基づいて前記加入者にサブキャリアを選択する段階を更に含んでいることを特徴とする請求項３に記載の方法。
【請求項５】
前記加入者がセル内トラフィックを測定する段階を更に含んでおり、前記加入者は前記セル内トラフィックロードのバランス取りに基づいて候補サブキャリアを選択することを特徴とする請求項２に記載の方法。
【請求項６】
前記基地局が、各クラスタのセル内トラフィックロードのバランスを取るために前記サブキャリアを選択する段階を更に含んでいることを特徴とする請求項５に記載の方法。
【請求項７】
前記加入者は、前記加入者のセットを割り当てられた後、新しいサブキャリアのセットの割当を受けるために新しいフィードバック情報を提出する段階と、その後、前記加入者が、前記新しいサブキャリアのセットの別の表示を受信する段階とを更に含んでいることを特徴とする請求項１に記載の方法。
【請求項８】
前記加入者が、チャネル及び干渉情報を測定するために、パイロット記号期間及びデータ期間からの情報を使用する段階を更に含んでいることを特徴とする請求項１に記載の方法。
【請求項９】
前記加入者は、サブキャリアのクラスタのＳＩＮＲと、パイロット期間中の各クラスタに対応する測定されたパワーとデータ期間中の測定されたパワーの間の差とに基づいて、候補サブキャリアを選択することを特徴とする請求項８に記載の方法。
【請求項１０】
前記加入者が、選択の間に、実質的に同様なＳＩＮＲを有するサブキャリアのクラスタを区別するために、前記パワー差を使用する段階を更に含んでいることを特徴とする請求項９に記載の方法。
【請求項１１】
前記加入者が、セル内トラフィックロードとセル間干渉の存在を分析するために、パイロット記号期間とデータトラフィック期間からの情報を使用する段階を更に含んでいることを特徴とする請求項８に記載の方法。

【請求項１２】
前記パイロット記号は、ＯＦＤＭ周波数帯域幅全体を占めることを特徴とする請求項１に記載の方法。
【請求項１３】
前記基地局から受信されたパイロット記号と同時に送信された異なるセルからの少なくとも１つの他のパイロット記号は、互いに衝突することを特徴とする請求項１２に記載の方法。
【請求項１４】
前記基地局が、前記基地局で入手可能な追加情報に基づいて、候補サブキャリアのセットからサブキャリアを選択する段階を更に含んでいることを特徴とする請求項１に記載の方法。
【請求項１５】
前記追加情報は、サブキャリアの各クラスタに関するトラフィックロード情報を含んでいることを特徴とする請求項１４に記載の方法。
【請求項１６】
前記トラフィックロード情報は、前記基地局のデータバッファによって提供されることを特徴とする請求項１５に記載の方法。
【請求項１７】
前記サブキャリアの表示は、ダウンリンク制御チャネルを介して受信されることを特徴とする請求項１に記載の方法。
【請求項１８】
前記複数のサブキャリアは、基地局が割り当てることのできる全てのサブキャリアから成ることを特徴とする請求項１に記載の方法。
【請求項１９】
前記フィードバック情報を提供する段階は、サブキャリアの候補のセットをサブキャリアのクラスタとして任意に順序付ける段階から成ることを特徴とする請求項１に記載の方法。
【請求項２０】
前記任意順序の候補クラスタは、最も望ましい候補クラスタが最初に掲載される順序に並んだクラスタから成ることを特徴とする請求項１９に記載の方法。
【請求項２１】
前記フィードバック情報は、候補クラスタをＳＩＮＲ値と共に表示するインデクス表示を含んでいることを特徴とする請求項１９に記載の方法。
【請求項２２】
前記各インデクスは、符号化及び変調速度を示していることを特徴とする請求項２１に記載の方法。
【請求項２３】
前記フィードバックを提供する段階は、候補クラスタを順次並べる段階から成ることを特徴とする請求項１に記載の方法。
【請求項２４】
前記加入者が、自身が各クラスタに採用を所望する符号化及び変調速度の表示を送信する段階を更に含んでいることを特徴とする請求項１に記載の方法。
【請求項２５】
前記符号化及び変調速度の表示は、符号化及び変調速度を示すＳＩＮＲインデクスから成ることを特徴とする請求項２４に記載の方法。
【請求項２６】
前記基地局が、前記サブキャリアの第１部分を割り当てて前記基地局と前記加入者の間にデータリンクを確立する段階と、次いで
前記基地局が、前記サブキャリアの第２部分を前記加入者に割り当てて通信帯域幅を広げる段階と、を更に含んでいることを特徴とする請求項１に記載の方法。

【請求項２７】
前記基地局は、セル内の各加入者にサブキャリアを割り当てて前記基地局と前記各加入者の間にデータリンクを確立した後で、前記第２部分を割り当てることを特徴とする請求項２６に記載の方法。
【請求項２８】
加入者の優先順位によって、前記基地局は、セル内の各加入者にサブキャリアを割り当てて前記基地局に対するデータリンクを確立する前に、前記第２部分を割り当てることを特徴とする請求項２６に記載の方法。
【請求項２９】
複数の加入者が使用を望んでいるサブキャリアのクラスタを表示するフィードバック情報を生成する、第１セル内の複数の加入者と、
前記フィードバック情報に応えて、セル間干渉回避とセル内トラフィックロードバランス取りに基づき、前記複数の加入者に対してクラスタ内のＯＦＤＭＡサブキャリアを割り当てるために、ＯＦＤＭＡ用のサブキャリア割当を行なう、前記第１セル内の第１基地局と、を備えていることを特徴とする装置。
【請求項３０】
複数の加入者が使用を望んでいるサブキャリアのクラスタを表示するフィードバック情報を生成する、第１セル内の複数の加入者と、
前記複数の加入者に対して、クラスタ内のＯＦＤＭＡサブキャリアを割り当てる、前記第１セル内の第１基地局と、を備えており、
前記複数の加入者は、それぞれ、前記第１基地局から受信したパイロット記号に基づいて前記複数のサブキャリアに関するチャネル及び干渉情報を測定し、前記複数の加入者のうちの少なくとも１人は、前記複数のサブキャリアから候補サブキャリアのセットを選択し、前記１人の加入者は、前記候補サブキャリアのセットに関するフィードバック情報を前記基地局に提供して、前記１人の加入者が使用するように前記第１基地局が前記サブキャリアのセットから選択したサブキャリアの表示を受信するようになっていることを特徴とする装置。
【請求項３１】
前記複数の加入者は、それぞれ、前記基地局及び前記複数の加入者にとって既知のパイロット記号の受信を継続的にモニターして、サブキャリアの各クラスタの信号対干渉＋ノイズ比（signal-plus-interference-to-noise ratio）（ＳＩＮＲ）を測定することを特徴とする請求項３０に記載の装置。
【請求項３２】
前記複数の加入者は、それぞれ、セル間干渉を測定し、少なくとも１人の加入者は、前記セル間干渉に基づいて候補サブキャリアを選択することを特徴とする請求項３１に記載の装置。
【請求項３３】
前記基地局は、セル間干渉回避に基づいて前記１人の加入者用のサブキャリアを選択することを特徴とする請求項３２に記載の装置。
【請求項３４】
前記複数の加入者は、それぞれ、セル内トラフィックを測定し、前記少なくとも１人の加入者は、前記セル内トラフィックロードバランス取りに基づいて候補サブキャリアを選択することを特徴とする請求項３１に記載の装置。
【請求項３５】
前記基地局は、サブキャリアの各クラスタのセル内トラフィックロードのバランスを取るためにサブキャリアを選択することを特徴とする請求項３４に記載の装置。
【請求項３６】
前記加入者は、前記加入者のセットを割り当てられた後、新しいサブキャリアのセットを受信するために新しいフィードバック情報を提出し、その後、前記新しいサブキャリアのセットの別の表示を受信することを特徴とする請求項３０に記載の装置。

【請求項３７】
前記少なくとも１人の加入者は、チャネル及び干渉情報を測定するために、パイロット記号期間及びデータ期間からの情報を使用することを特徴とする請求項３０に記載の装置。
【請求項３８】
前記少なくとも１人の加入者は、クラスタのＳＩＮＲと、パイロット期間中の各クラスタに対応する測定されたパワーとデータ期間中の測定されたパワーの間の差とに基づいて、候補サブキャリアを選択することを特徴とする請求項３０に記載の装置。
【請求項３９】
前記１人の加入者が、選択の間に、実質的に同様なＳＩＮＲを有するサブキャリアのクラスタを前記パワー差に基づいて区別することを特徴とする請求項３８に記載の装置。
【請求項４０】
前記少なくとも１人の加入者は、セル内トラフィックロードとセル間干渉の存在を分析するために、パイロット記号期間とデータトラフィック期間からの情報を使用することを特徴とする請求項３８に記載の装置。
【請求項４１】
前記パイロット記号は、ＯＦＤＭ周波数帯域幅全体を占めることを特徴とする請求項３８に記載の装置。
【請求項４２】
前記基地局から受信されたパイロット記号と同時に送信された異なるセルからの少なくとも１つの他のパイロット記号は、互いに衝突することを特徴とする請求項４１に記載の装置。
【請求項４３】
前記基地局が、前記基地局で入手可能な追加情報に基づいて、候補サブキャリアのセットからサブキャリアを選択することを特徴とする請求項３０に記載の装置。
【請求項４４】
前記追加情報は、サブキャリアの各クラスタに関するトラフィックロード情報から成ることを特徴とする請求項４３に記載の装置。
【請求項４５】
前記トラフィックロード情報は、前記基地局のデータバッファにより提供されることを特徴とする請求項４４に記載の装置。
【請求項４６】
前記サブキャリアの表示は、前記基地局と前記少なくとも前記少なくとも１人の加入者の間のダウンリンク制御チャネルを介して受信されることを特徴とする請求項３０に記載の装置。
【請求項４７】
前記複数のサブキャリアは、基地局が割り当てることのできる全てのサブキャリアから成ることを特徴とする請求項３０に記載の装置。
【請求項４８】
前記複数の加入者は、サブキャリアのクラスタとして任意に順序付けられた候補サブキャリアのセットから成るフィードバック情報を提供することを特徴とする請求項３０に記載の装置。
【請求項４９】
前記任意順序の候補クラスタは、最も望ましい候補クラスタが最初に掲載される順序に並んだクラスタから成ることを特徴とする請求項４８に記載の装置。
【請求項５０】
前記フィードバック情報は、候補クラスタをＳＩＮＲ値と共に表示するインデクス表示を含んでいることを特徴とする請求項４８に記載の装置。
【請求項５１】
前記各インデクスは符号化及び変調速度を示していることを特徴とする請求項５０に記載の装置。

【請求項５２】
前記フィードバック情報を提供することは、候補クラスタを順次並べることから成ることを特徴とする請求項３０に記載の装置。
【請求項５３】
前記１人の加入者が、自身が採用を所望する符号化及び変調速度の表示を送信することを特徴とする請求項３０に記載の装置。
【請求項５４】
前記符号化及び変調速度の表示は、符号化及び変調速度を示すＳＩＮＲインデクスから成ることを特徴とする請求項５３に記載の装置。
【請求項５５】
前記基地局が、前記サブキャリアの第１部分を割り当てて前記基地局と前記加入者の間にデータリンクを確立し、次いで、前記サブキャリアの第２部分を前記加入者に割り当てて通信帯域幅を広げることを特徴とする請求項３０に記載の装置。
【請求項５６】
前記基地局は、セル内の各加入者にサブキャリアを割り当てて前記基地局と前記各加入者の間にデータリンクを確立した後に、前記第２部分を割り当てることを特徴とする請求項５５に記載の装置。
【請求項５７】
加入者の優先順位によって、前記基地局は、セル内の各加入者にサブキャリアを割り当てて前記基地局に対するデータリンクを確立する前に、前記第２部分を割り当てることを特徴とする請求項５５に記載の装置。
【請求項５８】
基地局が、サブキャリアの第１の部分を割り当てて前記基地局と前記加入者の間にデータリンクを確立する段階と、次いで
前記基地局が、前記サブキャリアの第２部分を前記加入者に割り当てて通信帯域幅を広げる段階と、から成ることを特徴とする方法。
【請求項５９】
前記基地局は、セル内の各加入者にサブキャリアを割り当てて前記基地局と前記各加入者との間にデータリンクを確立した後、前記第２部分を割り当てることを特徴とする請求項５７に記載の方法。
【請求項６０】
基地局と加入者の間にデータリンクを確立するためにサブキャリアの第1の部分を割り当てるための手段と、
通信帯域幅を広げるために前記サブキャリアの第２の部分を加入者に割り当てるための手段と、を備えていることを特徴とする基地局。
【請求項６１】
前記基地局は、セル内の各加入者にサブキャリアを割り当てて前記基地局と前記各加入者の間にデータリンクを確立した後、前記第２部分を割り当てることを特徴とする請求項６０に記載の基地局。
【請求項６２】
セル内の複数の加入者と、
セル間干渉回避とセル内トラフィックロードバランス取りに基づき、前記複数の加入者に対してクラスタ内のＯＦＤＭＡサブキャリアを割り当てるために、ＯＦＤＭＡ用のサブキャリア割当を行なう、前記セル内の基地局と、を備えていることを特徴とする装置。
【発明の詳細な説明】
【技術分野】
【０００１】
本発明は、無線通信の分野に関し、より厳密には、本発明は、直交周波数分割多重化（ＯＦＤＭ）を使っている多重セル多重加入者無線システムに関する。
【背景技術】

【０００２】
直交周波数分割多重化（ＯＦＤＭ）は、周波数選択性チャネルで信号送信する際の効率的な変調スキームである。ＯＦＤＭでは、広い帯域幅が、多数の狭帯域サブキャリアに分割されるが、サブキャリアは互いに直交するように構成される。サブキャリア上で変調された信号は、並行して送信される。より詳しくは、Ｃｉｍｉｎｉ，Ｊｒ．による「直交周波数分割多重化を使ったデジタル移動チャネルの分析とシミュレーション」ＩＥＥＥ　Ｔｒａｎｓ．Ｃｏｍｍｕｎ．ＣＯＭ－３３巻、第７号、１９８５年７月、６６５－７５頁；Ｃｈｕｎｇ及びＳｏｌｌｅｎｂｅｒｇｅｒによる「３Ｇを超えて：ＯＦＤＭ及び動的パケット割当に基づく広帯域無線データアクセス」ＩＥＥＥコミュニケーションズマガジン、第３８巻、第７号、７８－８７頁、２０００年７月、を参照されたい。

【０００３】
多数の加入者のための多重アクセスをサポートするためにＯＦＤＭを使用する１つのやり方として、各加入者が割り当てられたタイムスロット内の全てのサブキャリアを使用する時分割多重アクセス（ＴＤＭＡ）がある。直交周波数分割多重アクセス（ＯＦＤＭＡ）は、ＯＦＤＭの基本的フォーマットを使用した多重アクセスの別の方法である。ＯＦＤＭＡでは、多数の加入者が、周波数分割多重アクセス（ＦＤＭＡ）に類似した様式で、異なるサブキャリアを同時に使用する。より詳しくは、Ｓａｒｉ及びＫａｒａｍによる「直交周波数分割多重アクセス及びＣＡＴＶネットワークへのその適用」、テレコミュニケーションに関するヨーロピアントランザクション、第９巻（６）、５０７－５１６頁、１９９８年１１月／１２月、及びＮｏｇｕｅｒｏｌｅｓ、Ｂｏｓｓｅｒｔ、Ｄｏｎｄｅｒ、及びＺｙａｂｌｏｖによる「ランダムＯＦＤＭＡ移動通信システムの改善性能」ＩＥＥＥ　ＶＴＣ’９８の会報、２５０２－２５０６頁、を参照されたい。

【０００４】
多重経路は周波数選択性フェージングを引き起こす。チャネルゲインは、それぞれのサブキャリア毎に異なる。更に、チャネルは、通常、異なる加入者に対して相関付けられていない。ある加入者にとってはフェージングが大きいサブキャリアでも、別の加入者にとっては高いチャネルゲインを提供する場合もある。従って、ＯＦＤＭＡシステムでは、各加入者が高チャネルゲインを享受できるように、サブキャリアを加入者に適応させて割り当てれば好都合である。より詳しくは、Ｗｏｎｇ他による「適応型サブキャリア、ビット及びパワー割当を備えたマルチユーザーＯＦＤＭ」ＩＥＥＥ　Ｊ．Ｓｅｌｅｃｔ．Ａｒｅａｓ　Ｃｏｍｍｕｎ．第１７巻（１０）、１７４７－１７５８号、１９９９年１０月、を参照されたい。

【０００５】
１つのセルの中で、各加入者がＯＦＤＭＡ内の異なるサブキャリアを有するように調整することができる。各加入者用の信号は互いに直交させることができるので、セル内干渉は殆ど起きない。しかしながら、積極的な周波数再使用プラン、例えば同一スペクトルを多数の隣接するセルで使用する場合、セル間干渉の問題が発生する。ＯＦＤＭＡシステムにおけるセル間干渉も周波数選択性であるのは明らかで、サブキャリアの適応割り当てを行ってセル間干渉の影響を緩和するのは、有用なことである。

【発明の開示】

【発明が解決しようとする課題】

【０００６】
ＯＦＤＭＡに関してサブキャリア割当を行うという１つのアプローチは、統合最適化オペレーションであるが、これは、全セル内の全加入者の行動とチャネルに関する知識が必要なばかりでなく、現在の加入者がネットワークを抜けたり新しい加入者がネットワークに加わったりした場合、その度毎に周波数の再調整が必要になる。これは、主に、加入者情報を更新するための帯域幅コストと統合最適化のための計算費用のせいで、実際の無線システムでは非実用的である場合が多い。

【課題を解決するための手段】

【０００７】

システムのためにサブキャリア選択を行う方法及び装置が記述されている。或る実施形態では、システムは、直交周波数分割多重アクセス（ＯＦＤＭＡ）を採用している。或る実施形態では、サブキャリア選択のための方法は、加入者が、基地局から受信したパイロット記号に基づいてサブキャリア毎にチャネル及び干渉情報を測定する段階と、加入者が候補サブキャリアのセットを選択する段階と、候補サブキャリアのセットに関するフィードバック情報を基地局に提供する段階と、加入者が使用するように基地局が選択したサブキャリアのセットの内のサブキャリアの表示を受信する段階と、を備えている。

【発明を実施するための最良の形態】

【０００８】

本発明は、本発明の各種実施形態に関する以下の詳細な説明及び添付図面から、より完全に理解頂けるであろうが、それらは、本発明を特定の実施形態に限定しようとするものではなく、その説明と理解を助けることだけを目的に提示するものである。

【０００９】

サブキャリア割当のための、分散型で複雑性を低減したアプローチについて説明する。ここに開示する技法を、例としてＯＦＤＭＡ（クラスタ）を使って説明する。しかしながら、本技法は、ＯＦＤＭＡをベースとするシステムに限定されるわけではない。本技法は、一般的には多重キャリアシステムに適用することができ、例えは、キャリアは、ＯＦＤＭＡのクラスタ、ＣＤＭＡの拡散コード、ＳＤＭＡ（空間分割多重アクセス）のアンテナビームなどとなる。或る実施形態では、サブキャリア割当は、各セル内で別々に行なわれる。各セル内では、個々の加入者（例えば、携帯電話など）に対する割当についても、割当毎にセル内の全加入者を考慮に入れて割当決定が行われる各セル内の加入者に対する統合割当とは反対に、新しい加入者がシステムに追加される度に漸進的に行なわれる。

【００１０】

ダウンリンクチャネルに関しては、各加入者は最初に全てのサブキャリアについてチャネルと干渉の情報を測定し、性能の良い（例えば、信号対干渉＋ノイズ比（signal-to-interference plus noise ratio）（ＳＩＮＲ）が高い）複数のサブキャリアを選択して、それら候補サブキャリアに関する情報を基地局にフィードバックする。このフィードバックには、全てのサブャリアについて又は一部のサブキャリアだけについてのチャネルと干渉の情報（例えば、信号対干渉＋ノイズ比（signal-to-interference-plus-noise-ratio）情報）が含まれる。一部のサブキャリアだけについての情報を提供する場合、加入者は、通常は性能が良好であるか又は他のサブキャリアよりも良好であるとの理由で、使用したいサブキャリアから順番にサブキャリアのリストを提供する。

【００１１】

加入者からこの情報を受信すると、基地局は、基地局で入手可能な追加情報、例えば各サブキャリアのトラフィックロード情報、周波数帯域毎の基地局で待機中のトラフィックリクエストの量、周波数帯域が過度に使用されていないか、及び／又は加入者がどれほどの間情報送信を待っているか等の情報を利用して、候補の中からサブキャリアを更に選択する。或る実施形態では、隣接するセルのサブキャリアローディング情報も、基地局間で交換される。基地局はこの情報をサブキャリア割当に使用してセル間干渉を低減する。

【００１２】

或る実施形態では、フィードバックに基づいて基地局が割当チャネルを選択する結果として、符号化／変調速度の選択が行なわれる。このような符号化／変調速度は、使用に好ましいと分かったサブキャリアを特定する際、加入者が特定してもよい。例えば、ＳＩＮＲがある閾値（例えば１２ｄＢ）より低い場合、直角位相変換打鍵（ＱＰＳＫ）変調が使用されるが、そうでない場合は１６直交振幅変調（ＱＡＭ）が使用される。次いで、基地局は、加入者にサブキャリア割当及び／又は使用される符号化／変調速度を通知する。

【００１３】

或る実施形態では、ダウンリンクサブキャリア割当に関するフィードバック情報は、アップリンクアクセスチャネルを通して基地局に送信されるが、これは、送信タイムスロット毎に短い時間、例えば各１０ミリ秒タイムスロット内の４００マイクロ秒内に起きる。或

る実施形態では、アクセスチャネルは、周波数帯域幅全体を占める。基地局は、各サブキャリアのアップリンクＳＩＮＲをアクセスチャネルから直接収集することができる。アップリンクサブキャリアのＳＩＮＲ並びにトラフィックロード情報は、アップリンクサブキャリア割当に使用される。

【００１４】

何れの方向についても、基地局は加入者毎にサブキャリア割当の最終決定を行なう。

【００１５】

以下の説明の中では、チャネルと干渉の感知の方法、加入者から基地局への情報フィードバックの方法、及びサブキャリア選択のために基地局が使用するアルゴリズムを始めとして、選択的サブキャリア割当についても開示する。

【００１６】

以下の説明では、本発明を全体的に理解してもらうために多くの詳細事項を説明している。しかしながら、当業者には自明であるように、本発明はこれら特定の詳細事項なしに実施することができる。別の例では、本発明をあいまいにするのを避けるために、周知の構造と装置を、詳細にではなくブロック図の形態で示している。

【００１７】

以下の詳細な説明の或る部分は、コンピュータメモリ内のデータビットに関するオペレーションのアルゴリズム及び記号表現の面から提示されている。これらアルゴリズム的記述及び表現は、データ処理技術に熟練した者によって、彼らの作業内容を他の当業者に最も効果的に伝えるために使用される手段である。あるアルゴリズムがここにある場合、一般的には、所望の結果に導く首尾一貫した順序のステップであると考えられる。ステップは、物理量を物理的に操作することを必要とするものである。必ずしもというわけではないが、通常は、これらの量は、記憶、送信、組合わせ、比較、その他のやり方で操作することのできる電気又は磁気信号の形態を取る。時には、主に共通に使用するという理由から、これら信号を、ビット、数値、要素、記号、文字、項、数などとして言及するのが好都合であると実証されている。

【００１８】

しかし、上記及び類似の用語は、適当な物理量に対応付けられるもので、これらの量に用いられる便宜上のラベルに過ぎないことに留意頂きたい。以下の説明で明らかにする以外で特に明記しない限り、記述全般を通して、「処理する」又は「電算する」又は「計算する」又は「判定する」又は「表示する」などの用語を使った説明は、コンピュータシステムのレジスタ及びメモリ内の物理（電子）量として表現されるデータを操作して、コンピュータシステムのメモリ又はレジスタ又は他のそのような情報記憶装置、伝送又は表示装置内で物理量として同じように表現される他のデータに変換する、コンピュータシステム又は類似の電子計算装置の動作及び処理を指すものと理解されたい。

【００１９】

本発明は、このオペレーションを実行するための装置にも関係する。本装置は、必要な目的のために特別に構成してもよいし、コンピュータ内に記憶されたコンピュータプログラムにより選択的に起動又は再構成される汎用コンピュータを備えていてもよい。このようなコンピュータプログラムは、限定するわけではないが、フロッピーディスク、光ディスク、ＣＤ―ＲＯＭ、及び磁気光ディスクを始めとするあらゆる種類のディスク、読み出し専用メモリ（ＲＯＭ）、ランダムアクセスメモリ（ＲＡＭ）、ＥＰＲＯＭ、ＥＥＰＲＯＭ、磁気又は光学カード、電子命令を記憶するのに適した全ての種類の媒体など、それぞれにコンピュータシステムバスに連結されたコンピュータ読み取り可能記憶媒体に記憶される。

【００２０】

ここに提示するアルゴリズム及び表示は、特定のコンピュータ又は他の装置に本来的に関係しているわけではない。各種汎用システムをここに述べる教示に準じたプログラムを使って使用してもよいし、又、必要な方法のステップを実行するためにより特殊化した装置を構成するのも便利であることも分かっている。各種上記システムに必要な構造は、以下

の説明から明らかとなるであろう。更に、本発明は、何れの特定のプログラム言語に関連付けて説明しているわけでもない。なお、ここに説明する本発明の教示を実施するために各種プログラム言語を使用してもよいと理解頂きたい。

【００２１】

機械読み取り可能媒体には、機械（例えばコンピュータ）が読み取り可能な形態で情報を記憶又は送信するためのあらゆる機構が含まれている。例えば、機械読み取り可能媒体には、読み取り専用メモリ（ＲＯＭ）、ランダムアクセスメモリ（ＲＡＭ）、磁気ディスク記憶媒体、光学記憶媒体、フラッシュメモリ装置、電気的、光学的、音響的又は他の形態の伝搬信号（例えば、搬送波、赤外線信号、デジタル信号など）等が含まれている。

【００２２】

サブキャリア・クラスタリング

ここに説明する技術は、データトラフィックチャネル用のサブキャリア割当に着眼している。セルラーシステムには、通常、制御情報の交換及び他の目的のために事前に割り当てられた別のチャネルがある。これらのチャネルは、ダウンリンク及びアップリンク制御チャネル、アップリンクアクセスチャネル、及び時間・周波数同期チャネルを含んでいることが多い。

【００２３】

図１Ａは、サブキャリア１０１のような複数のサブキャリアとクラスタ１０２を示している。クラスタ１０２のようなクラスタは、図１Ａに示すように、少なくとも１つの物理的サブキャリアを保有している論理ユニットとして定義される。クラスタは、連続した又はばらばらのサブキャリアを保有することができる。クラスタとそのサブキャリアの間のマッピングは、固定されていても再構成可能であってもよい。後者の場合、基地局は、加入者に何時クラスタが再定義されるかを通知する。或る実施形態では、周波数スペクトルは５１２個のサブキャリアを含んでいて、各クラスタは４個の連続したサブキャリアを含んでおり、結果的に１２８個のクラスタとなる。

【００２４】

代表的サブキャリア／クラスタ割当手続き

図１Ｂは、加入者へのクラスタ割当のプロセスの或る実施形態を示すフロー図である。本プロセスは、ハードウェア（例えば、専用論理、回路など）、ソフトウェア（例えば、汎用コンピュータシステム又は専用機械などで稼動するもの）、又は両者の組み合わせから成る処理論理によって実行される。

【００２５】

図１Ｂに示すように、各基地局は、そのセル（又はセクター）内の各加入者にパイロットＯＦＤＭ記号を周期的に同報通信する（処理ブロック１０１）。サウンディングシーケンス又は信号とも呼ばれるパイロット記号は、基地局と加入者の双方に既知である。或る実施形態では、各パイロット記号はＯＦＤＭ周波数帯域幅全体をカバーしている。パイロット記号は、それぞれのセル（又はセクター）毎に異なっていてもよい。パイロット記号は、複数の目的、即ち、時間及び周波数の同期化、クラスタ割当のためのチャネル評価及び信号対干渉／ノイズ（ＳＩＮＲ）比測定などに使用される。

【００２６】

次に、各加入者は、継続的にパイロット記号の受信をモニターし、セル間干渉及びセル内トラフィックを含め、各クラスタのＳＩＮＲ及び／又は他のパラメータを測定する（処理ブロック１０２）。この情報に基づいて、各加入者は、相対的に性能が良好な（例えば、高ＳＩＮＲ低トラフィックローディングの）１つ又は複数のクラスタを選択して、これらの候補クラスタに関する情報を所定のアップリンクアクセスチャネルを通して基地局にフィードバックする（処理ブロック１０３）。例えば、１０ｄＢより高いＳＩＮＲ値は、性能が良好であることを表す。同様に、クラスタ利用率５０％未満も、良好な性能を表している。各加入者は、他よりも相対的に性能が良好なクラスタを選択する。この選択により、各加入者は測定されたパラメータに基づいて使用が望ましいと思われるクラスタを選択することになる。

【００２７】
或る実施形態では、各加入者は各サブキャリアクラスタのＳＩＮＲを測定して、それらＳＩＮＲ測定値をアクセスチャネルを通して基地局に報告する。ＳＩＮＲ値は、クラスタ内の各サブキャリアのＳＩＮＲ値の平均を含んでいる。代わりに、クラスタのＳＩＮＲ値は、クラスタ内のサブキャリアのＳＩＮＲ値中最悪のＳＩＮＲであってもよい。更に別の実施形態では、クラスタ内のサブキャリアのＳＩＮＲ値の加重平均を使用して、クラスタに関するＳＩＮＲを生成している。これは、サブキャリアに適用される重み付けが異なるダイバーシティクラスタで特に有用である。

【００２８】
各加入者から基地局への情報のフィードバックは、各クラスタのＳＩＮＲ値を含んでおり、加入者が使用を望む符号化／変調速度も示している。フィードバック内の情報の順序を基地局が知っている限り、フィードバック内のどのＳＩＮＲ値がどのクラスタに対応しているかを示すためにクラスタインデクスが必要になることはない。別の実施形態では、フィードバック内の情報は、加入者にとってどのクラスタが相対的に最高の性能を有しているかに従って順序付けられている。このような場合は、付帯するＳＩＮＲ値がどのクラスタに対応しているかを示すために、インデクスが必要である。

【００２９】
加入者からフィードバックを受信すると、基地局は、次に、候補の中から加入者用に１つ又は複数のクラスタを選択する（処理ブロック１０４）。基地局は、基地局で入手可能な追加情報、例えば、各サブキャリアに関するトラフィックロード情報、各周波数帯域について基地局で待機中のトラフィックリクエストの量、周波数帯域が過剰使用されていないか、情報送信のためにどれほどの間加入者が待っているか、等の情報を利用する。隣接するセルのサブキャリアローディング情報も、基地局間で交換することができる。基地局は、この情報をサブキャリア割当に使用して、セル間干渉を低減する。

【００３０】
クラスタ選択の後、基地局は、ダウンリンク共通制御チャネルを通して、又は加入者への接続が既に設定されている場合には専用のダウンリンクトラフィックチャネルを通して、クラスタ割当について加入者に通知する（処理ブロック１０５）。或る実施形態では、基地局は、適切な変調／符号化速度についても加入者に通知する。

【００３１】
一旦、基本的な通信リンクが設定されると、各加入者は、専用のトラフィックチャネル（例えば、１つ又は複数の所定のアップリンクアクセスチャネル）を使って、継続してフィードバックを基地局に送信することができる。

【００３２】
或る実施形態では、基地局は、加入者が使用することになるクラスタを全て、一度に割り当てる。別の実施形態では、基地局は、最初に、ここでは基本クラスタと呼ぶ複数のクラスタを割り当て、基地局と加入者との間にデータリンクを設定する。基地局は、次に、ここでは補助クラスタと呼ぶ更に多くのクラスタを加入者に割り当て、通信帯域幅を広げる。基本クラスタの割当には高い優先順位が与えられ、補助クラスタの割当には低い優先順位が与えられる。例えば、基地局は、先ず、加入者に対して基本クラスタの割当を確実にした上で、次いで加入者からの補助クラスタに関する更なる要求を満たそうとする。代わりに、基地局は、基本クラスタを他の加入者に割り当てる前に、補助クラスタを１つ又は複数の加入者に割り当ててもよい。例えば、基地局は、何れかのクラスタを他の加入者に割り当てる前に、基本及び補助クラスタを１人の加入者に割り当ててもよい。或る実施形態では、基地局は、基本クラスタを新しい加入者に割り当てて、その後、クラスタを要求している他の加入者がいるかどうかを判定する。いなければ、基地局は、新しい加入者に補助クラスタを割り当てる。

【００３３】
場合によっては、処理論理は、上記プロセスを繰り返すことによって再教育を実行する（処理ブロック１０６）。再教育は周期的に行なわれる。この再教育は、加入者の移動及び

あらゆる干渉の変化を補償する。或る実施形態では、各加入者は、基地局に、その更新されたクラスタの選択及び付帯するＳＩＮＲを報告する。すると、基地局は、再度選択し直して、加入者に新しいクラスタ割当を通知する。再教育は、基地局が開始することができ、その場合、基地局は、特定の加入者にその更新されたクラスタ選択を報告するように要求する。再教育は、チャネル劣化が見られた場合には加入者側からも開始できる。

【００３４】

適応変調及び符号化

或る実施形態では、異なる変調及び符号化速度を使用して、異なるＳＩＮＲを有するチャネルで信頼性の高い送信をサポートする。非常に低いＳＩＮＲで信頼性を改善するために、複数のサブキャリアによる信号拡散を使用してもよい。

【００３５】

符号化／変調表の一例を下表１に示す。

【表１】

表１

スキーム	変調	符号化速度
0	ＱＰＳＫ，１／８拡散	１／２
1	ＱＰＳＫ，１／４拡散	１／２
2	ＱＰＳＫ，１／２拡散	１／２
3	ＱＰＳＫ	１／２
4	８ＰＳＫ	２／３
5	１６ＱＡＭ	３／４
6	６４ＱＡＭ	５／６

【００３６】

上記例では、１／８拡散は、１つのＱＰＳＫ変調記号が８つのサブキャリアに亘って繰り返されることを示している。反復／拡散は、更に、タイムドメインにまで拡張される。例えば、１つのＱＰＳＫ記号を２つのＯＦＤＭ符号の４つのサブキャリアに亘って繰り返すことができ、結果的に１／８拡散となる。

【００３７】

符号化／変調速度は、最初のクラスタ割当及び速度選択後に受信者側で観測されるチャネル状態に従って適応変更が行われる。

【００３８】

パイロット記号及びＳＩＮＲ測定

或る実施形態では、各基地局は、パイロット記号を同時に送信し、各パイロット記号は図２Ａ－Ｃに示すようにＯＦＤＭ周波数帯域幅全体を占めている。図２Ａ－Ｃに示すように、パイロット記号２０１は、セルＡ、Ｂ、及びＣそれぞれに関してＯＦＤＭ周波数帯域全体を横断して広がっていることが分かる。或る実施形態では、各パイロット記号は、１２８マイクロ秒の長さ又は持続時間にガードタイムが付いて、合計で凡そ１５２マイクロ秒となっている。各パイロット期間の後、所定数のデータ期間があって、その後にパイロット記号の別のセットが続いている。或る実施形態では、各パイロットの後にデータ送信に使用される４つのデータ期間があり、各データ期間は１５２マイクロ秒となっている。

【００３９】

加入者は、パイロット記号からクラスタ毎のＳＩＮＲを評価する。或る実施形態では、加入者は、最初に、干渉又はノイズが無いものとして、振幅及び位相を含め、チャネル応答を評価する。チャネルの評価が済むと、加入者は、受信信号から干渉／ノイズを計算する。

【００４０】

評価されたＳＩＮＲ値は、大きいものから順に並べられ、ＳＩＮＲ値の大きいクラスタが

選択される。或る実施形態では、選択されたクラスタは、システムがサポートする（低速ではあるが）信頼性のある送信を可能にする最小ＳＩＮＲよりも大きいＳＩＮＲ値を有している。選択されるクラスタの数は、フィードバック帯域幅及びリクエスト送信速度によって異なる。或る実施形態では、加入者は、常にできるだけ多くのクラスタに関する情報を送ろうと務め、そこから基地局が選択する。

【００４１】

評価されたＳＩＮＲ値は、上記のように各クラスタに対する適当な符号化／変調速度を選択するのにも使用される。適当なＳＩＮＲ指標付けスキームを使用すると、ＳＩＮＲインデクスは、加入者が使用を望む特定の符号化及び変調速度も表示することができる。なお、同一の加入者の場合でも、異なるクラスタは異なる変調／符号化速度を有することもある。

【００４２】

パイロット記号は、セル間の干渉を判定するのに追加の目的を持っている。複数のセルのパイロットは同時に同報通信されるので、（それらが全周波数帯域を占めるため）互いに干渉し合う。パイロット記号のこの衝突を利用して、最悪の場合のシナリオとしての干渉の量を求めることができる。従って、或る実施形態では、本方法を使った上記ＳＩＮＲ評価は、測定された干渉レベルが、全ての干渉源が稼働していると仮定している最悪の場合のシナリオであるという点で、慎重である。このように、パイロット記号の構造は、パケット送信システムにおける最悪時のＳＩＮＲを検出するのに使用するために、周波数帯域全体を占め、異なるセル間の衝突を発生させるようになっている。

【００４３】

データトラフィック期間の間、加入者は干渉のレベルを再度判定することができる。データトラフィック期間は、セル内トラフィック並びにセル間干渉レベルを評価するために使用される。具体的には、パイロット及びトラフィック期間中のパワー差を使用して、望ましいクラスタを選択するために、（セル内）トラフィックローディングとセル間干渉を感知する。

【００４４】

或るクラスタでは、隣接するセル内で使用されていないために、干渉レベルが比較的低いことになる。例えば、セルＡでは、クラスタＡに関して、（セルＣでは使用されているが）セルＢでは使用されていないので干渉は殆ど無い。同様に、セルＡでは、クラスタＢは、セルＣでは使用されていないがセルＢでは使用されているので、セルＢから僅かな干渉を被る。

【００４５】

この評価に基づく変調／符号化速度は、爆発的なパケット送信に起因する頻繁な干渉変化に対して強い。それは、速度の予測が、全ての干渉源が送信中であるという最悪時のシナリオに基づいているためである。

【００４６】

或る実施形態では、加入者はパイロット記号期間とデータトラフィク期間の双方から入手可能な情報を使って、セル内トラフィックロードとセル間干渉両方の存在を分析する。加入者の目的は、加入者が使用したいと思うクラスタについて基地局に表示を提供することである。理想的には、加入者による選択の結果は、チャネルゲインが高く、他のセルからの干渉が低く、利用可能性が高いクラスタということになる。加入者は、その結果を含んでいるフィードバック情報を提供し、所望のクラスタを、順番に又はここに記載していない方法でリスト表示する。

【００４７】

図３は、加入者処理の或る実施形態を示している。処理は、ハードウェア（例えば、専用の論理、回路など）、ソフトウェア（例えば、汎用コンピュータシステム又は専用機械上で実行されるものなど）、又は両者の組み合わせを備えている処理論理により実行される。

【００４８】

図３に示すように、チャネル／干渉評価処理ブロック３０１は、パイロット記号に応答してパイロット期間内に、チャネル及び干渉評価を実行する。トラフィック／干渉分析処理ブロック３０２は、信号情報及びチャネル／干渉評価ブロック３０１からの情報に応答して、データ期間内に、トラフィック及び干渉分析を実行する。

【００４９】

クラスタの順序付け及び速度予測処理ブロック３０３は、チャネル／干渉評価処理ブロック３０１並びにトラフィック／干渉分析処理ブロック３０２の出力に連結され、速度予測と共にクラスタの順序付けと選択を行なう。

【００５０】

クラスタ順序付け処理ブロック３０３の出力は、クラスタリクエスト処理ブロック３０４に入力されるが、これはクラスタと変調／符号化速度を要求する。これら選択の表示は基地局に送られる。或る実施形態では、各クラスタのＳＩＮＲは、アクセスチャネルを通して基地局に報告される。クラスタ選択にこの情報を使って、クラスタが厳しいセル内トラフィックローディングに陥ったり、及び／又は他のセルからの激しい干渉を受けたりするのを回避する。即ち、新しい加入者は、厳しいセル内トラフィックローディングが或る特定のクラスタに関し既に存在する場合、当該クラスタの使用を割り当てられることはない。また、干渉が激しくてＳＩＮＲが低く、低速送信しかできないか又は信頼性の高い送信が全くできないような場合には、そのクラスタは割り当てられない。

【００５１】

処理ブロック３０１によるチャネル／干渉評価は、全帯域幅パイロット記号が複数のセル内で同時に同報通信されていることに起因して発生する干渉を監視することにより当該技術では周知である。干渉情報は、処理ブロック３０２に送られ、処理ブロック３０２はその情報を使用して以下の方程式を解く：

$H_i S_i + I_i + n_i = y_i$

ここに、S_iはサブキャリア（ｆｒｅｑ．ｂａｎｄ）ｉの信号を表し、I_iはサブキャリアｉの干渉であり、n_iはサブキャリアｉに対応付けられたノイズであり、y_iはサブキャリアｉの観察である。５１２サブキャリアの場合、ｉは０から５１１の範囲にある。I_i及びn_iは、分離されておらず１つの量と考えてもよい。干渉／ノイズ及びチャネルゲインH_iは分かっていない。パイロット期間中に、パイロット記号を表す信号S_i及び観察y_iが分かり、これにより干渉又はノイズがない場合についてのチャネルゲインH_iを求めることができる。一旦これが分かると、H_i、S_i、及びy_iが全て分かっているので、方程式に当てはめて、データ期間中の干渉／ノイズを求めることができる。

【００５２】

処理ブロック３０１と３０２からの干渉情報を使って、加入者は、望ましいクラスタを選択する。或る実施形態では、処理ブロック３０３を使って、加入者はクラスタを順序付けし、そのようなクラスタを使って利用可能となるはずのデータ速度を予測する。予測されたデータ速度情報は、事前に計算されたデータ速度値を載せたルックアップ表から入手することができる。このようなルックアップ表は、各ＳＩＮＲとそれに対応付けられた望ましい送信速度の対を記憶している。この情報に基づいて、加入者は、所定の性能基準に基づき使用を希望するクラスタを選択する。クラスタの順位リストを使って、加入者は、加入者が知っている符号化及び変調速度と共に所望のクラスタを要求して、所望のデータ速度を実現する。

【００５３】

図４は、パワー差に基づいてクラスタを選択するための装置の或る実施形態である。このアプローチは、パイロット記号期間とデータトラフィック期間の両方の間に利用可能な情報を使用して、エネルギー検出を行なう。図４の処理は、ハードウェア（例えば、専用論理、回路など）、ソフトウェア（例えば、汎用コンピュータシステム又は専用機械上で実行されるものなど）、又は両者の組合わせで実施される。

【００５４】

図４に示すように、加入者は、パイロット期間内に各クラスタ毎にＳＩＮＲ評価を行うた

めのＳＩＮＲ評価処理ブロック４０１、パイロット期間内に各クラスタ毎にパワー計算を行うためのパワー計算処理ブロック４０２、及びデータ期間内に各クラスタ毎にパワー計算を行なうためのパワー計算処理ブロック４０３を含んでいる。減算器４０４は、処理ブロック４０３からのデータ期間中のパワー計算を、処理ブロック４０２からのパイロット期間中のパワー計算から差し引く。減算器４０４の出力は、パワー差順序付け（及びグループ選択）処理ブロック４０５へ入力され、当該ブロックでは、ＳＩＮＲと、パイロット期間とデータ期間の間のパワー差とに基づいて、クラスタの順序付けと選択を行なう。一旦、クラスタが選択されると、加入者は、選択されたクラスタ及び符号化／変調速度を処理ブロック４０６で要求する。

【００５５】

より具体的には、或る実施形態では、パイロット期間中の各クラスタの信号パワーは、トラフィック期間中のそれと、以下に基づいて比較される：

【００５６】

【数１】

$$P_P = P_S + P_I + P_N,$$
$$P_D = \begin{cases} P_N, & \text{信号及び干渉無し} \\ P_S + P_N, & \text{信号のみ有り} \\ P_I + P_N, & \text{干渉のみ有り} \\ P_S + P_I + P_N, & \text{信号と干渉有り} \end{cases}$$
$$P_P - P_D = \begin{cases} P_S + P_I, & \text{信号と干渉無し} \\ P_I, & \text{信号のみ有り} \\ P_S, & \text{干渉のみ有り} \\ 0, & \text{信号と干渉有り} \end{cases}$$

【００５７】

ここに、P_Pはパイロット期間中に測定された各クラスタに対応するパワーであり、P_0はトラフィック期間中に測定されたパワーであり、P_Sは信号パワーであり、P_Iは干渉パワーであり、P_Nはノイズパワーである。

或る実施形態では、加入者は、可能であれば、P_P／（P_P－P_D）が比較的大きい（例えば、１０ｄＢのような閾値よりも大きい）クラスタを選択し、P_P／（P_P－P_D）が比較的小さい（例えば、１０ｄＢのような閾値よりも小さい）クラスタを避ける。

代わりに、差は、以下のような、クラスタ内の各加入者毎に、パイロット期間中に観測されるサンプルとデータトラフィック期間中に観測されるサンプルの間のエネルギー差に基づいていてもよい。

【００５８】

【数２】

$$\Delta_I = \left| y_i^P \right| - \left| y_I^D \right|$$

【００５９】

このように、加入者は全てのサブキャリアについて差を合算する。

【００６０】

実際の実施形態にもよるが、加入者はクラスタを選択するために、以下の測度、即ちＳＩＮＲとP_P－P_Dの組み合わせ関数を使用する。

$\beta = f$（ＳＩＮＲ，P_P／（P_P－P_D））

ここに、ｆは２つの入力の関数である。ｆの１つの例は、加重平均（例えば、等重量）である。代わりに、加入者は、ＳＩＮＲに基づいてクラスタを選択し、同じようなＳＩＮＲを有するクラスタを判別するのに、パワー差P_P－P_Dだけを使用してもよい。差は、閾値（例えば、１ｄＢ）よりも小さくてもよい。

【００６１】
ばらつきを小さくして精度を上げるために、ＳＩＮＲと$P_P - P_D$両者の測定値を時間について平均してもよい。或る実施形態では、移動平均時間ウインドウを使っており、これは統計的異常を平均するには十分に長く、且つチャネルと干渉の時間変化特性を捉えるには十分に短くなっており、例えば１０ミリ秒である。

【００６２】
ダウンリンククラスタ割当のためのフィードバックフォーマット

或る実施形態では、ダウンリンクの場合、フィードバックは、選択されたクラスタのインデクスとそのＳＩＮＲの両方を保有している。任意のクラスタフィードバックの代表的なフォーマットを図５に示す。図５に示すように、加入者は、クラスタとその付帯するＳＩＮＲ値を示すため、クラスタインデクス（ＩＤ）を提供する。例えば、フィードバックでは、加入者は、クラスタＩＤ１（５０１）及び当該クラスタのＳＩＮＲであるＳＩＮＲ１（５０２）、クラスタＩＤ２（５０３）及び当該クラスタのＳＩＮＲであるＳＩＮＲ２（５０４）、及びクラスタＩＤ３（５０５）及び当該クラスタのＳＩＮＲであるＳＩＮＲ３（５０６）などを提供する。クラスタのＳＩＮＲは、サブキャリアのＳＩＮＲの平均を使って作ることができる。こうして、複数の任意のクラスタを候補として選択することができる。上記のように、選択されたクラスタは、優先順位を示すためにフィードバック内で順序付けることもできる。或る実施形態では、加入者は、クラスタの優先順位リストを作成し、ＳＩＮＲ情報を優先順位の降順で返信する。

【００６３】
通常、ＳＩＮＲ自身の代わりに、ＳＩＮＲレベルに対するインデクスを表示すれば、クラスタにとって適当な符号化／変調を示すのに十分である。例えば、適応符号化／変調の８つの異なる速度を示すために、３ビットフィールドをＳＩＮＲ指標付けに使用してもよい。

【００６４】
代表的基地局

基地局は、リクエストを行っている加入者に望ましいクラスタを割り当てる。或る実施形態では、加入者に割り当てるクラスタの利用可能性は、クラスタ上の合計トラフィックロードに左右される。従って、基地局は、ＳＩＮＲが高いだけでなく、トラフィックロードが低いクラスタを選択する。

【００６５】
図１３は、基地局の或る実施形態のブロック図である。図１３に示すように、クラスタ割当及びロードスケジューリング制御装置１３０１（クラスタアロケータ）は、各加入者に指定されたクラスタのダウンリンク／アップリンクＳＩＮＲ（例えば、ＯＦＤＭ受信機１３０５から受信するＳＩＮＲ／速度インデクス信号１３１３）と、ユーザーデータ、即ち待ち行列充満度／トラフィックロード（例えば、マルチユーザーデータバッファ１３０２からのユーザーデータバッファ情報１３１１を介して）とを含め、必要な全ての情報を収集する。この情報を使って、制御装置１３０１は、各ユーザー毎にクラスタ割当及びロードスケジューリングを決定し、決定情報をメモリ（図示せず）に記憶する。制御装置１３０１は、制御信号チャネル（例えばＯＦＤＭ受信機１３０５を介した制御信号／クラスタ割当１３１２）を通して、決定について加入者に通知する。

【００６６】
或る実施形態では、制御装置１３０１は、更に、システムのトラフィックロードを知っているので、ユーザーアクセスに対する進入制御を行なう。これは、進入制御信号１３１０を使ってユーザーデータバッファ１３０２を制御することにより行なわれる。

【００６７】
ユーザー１－Ｎのパケットデータは、ユーザーデータバッファ１３０２に記憶される。ダウンリンクについては、制御装置１３０１の制御により、マルチプレクサ１３０１は、ユーザーデータを送信待ちの（クラスタ１－Ｍの）クラスタデータバッファにロードする。アップリンクについては、マルチプレクサ１３０３は、クラスタバッファのデータを対応

するユーザーバッファに送信する。クラスタバッファ１３０４は、（ダウンリンクの）ＯＦＤＭ送受信器１３０５を通して送信されることになる信号と、送受信器１３０５から受信した信号を記憶する。或る実施形態では、各ユーザーは複数のクラスタを占有し、各クラスタは複数のユーザーによって共有される（時分割多重化式の場合）。

【００６８】

グループベースのクラスタ割当

別の実施形態では、ダウンリンクの場合、クラスタはグループに分割される。各グループは、複数のクラスタを含んでいてもよい。図６は、代表的な分割例を示している。図６に示すように、グループ１－４は、グループ分けの結果として各グループに入れられたクラスタを指す矢印で示されている。或る実施形態では、各グループ内のクラスタは、帯域幅全体に亘って遠く離されている。或る実施形態では、各グループ内のクラスタは、チャネルコヒーレンス帯域幅、即ちその中のチャネル応答が概ね同じである帯域幅、よりも更に離されている。コヒーレント帯域幅の代表的な値は、多くのセルラーシステムについて１００ｋＨｚである。これは、各グループ内の周波数ダイバーシティを改善し、グループ内のクラスタの少なくとも一部が高ＳＩＮＲを提供できる確率を上げることになる。クラスタは、グループに割り当てられる。グループベースのクラスタ割当の目的には、クラスタ指標付けのデータビットを減じ、これにより、クラスタ割当用のフィードバックチャネル（情報）と制御チャネル（情報）の帯域幅要件を緩和することである。グループベースのクラスタ割当は、セル間干渉を低減するためにも使用される。

【００６９】

基地局からパイロット信号を受信した後、加入者は１つ又は複数のクラスタグループに関するチャネル情報を同時に又は順次返送する。或る実施形態では、グループの幾つかに関する情報しか基地局には返送されない。グループの選定及び順序付けには、チャネル情報、セル間干渉レベル、及び各クラスタでのセル内トラフィックロードに基づいて、多くの判定基準を使用することができる。

【００７０】

或る実施形態では、加入者は、最初に、全体性能が最良のグループを選択し、そのグループのクラスタのＳＩＮＲ情報をフィードバックする。加入者は、グループを、ＳＩＮＲが事前に定義された閾値より高いクラスタの番号に基づいて順序付けする。グループ内の全てのクラスタのＳＩＮＲを送信することにより、全てのクラスタインデクスではなく、グループのインデクスだけを送信すればよくなる。このように、各グループのフィードバックは、一般的には２種類の情報、即ち、グループインデクス及び当該グループ内の各クラスタのＳＩＮＲ値を保有している。図７に、グループベースのクラスタ割当を表示する代表的フォーマットを示す。図７に示すように、グループＩＤであるＩＤ１の後には、グループ内のクラスタそれぞれのＳＩＮＲ値が続く。これによりフィードバックのオーバーヘッドが大幅に低減できる。

【００７１】

加入者からのフィードバック情報を受信すると、基地局のクラスタアロケータは、１つ又は複数のグループから、利用可能であれば、複数のクラスタを選択し、次いでそのクラスタを加入者に割り当てる。この選択は、基地局の媒体アクセス制御部での割当により行なわれる。

【００７２】

更に、多重セル環境では、グループは、異なるセルに関係付けられた異なる優先順位を有していてもよい。或る実施形態では、加入者によるグループの選択には、グループの優先順位でバイアスが掛かっており、これは、ある加入者は、あるグループの使用権に関して他の加入者よりも高い優先順位を有していることを意味している。

【００７３】

或る実施形態では、或る加入者と或るクラスタグループの間には何ら固定された関係はないが、別の実施形態では、そのような固定された関係が存在する。加入者と１つ又は複数のクラスタグループの間に固定された関係を有する実施形態では、フィードバック情報内

のグループインデクスは、この情報が加入者及び基地局の双方にとってデフォルトにより既知であるため、省略することができる。

【００７４】

別の実施形態では、基地局から加入者に送信されるパイロット信号は、各クラスタの利用可能性も示しており、例えば、パイロット信号は、どのクラスタが他の加入者に対して既に割り当てられているか、及びどのクラスタが新規割当に利用可能であるか、を示す。例えば、基地局は、クラスタのサブキャリアに関してパイロットシーケンス１１１１　１１１１を送信して、当該クラスタが利用可能である旨を表し、１１１１－１－１－１－１を送信して当該クラスタが利用可能でない旨を表す。受信機では、加入者は、先ず、当技術では周知の信号処理方法、例えば相関方法を使って２つのシーケンスを区別し、次いでチャネルと干渉レベルを評価する。

【００７５】

本発明を加入者により入手されたチャネル特性と組み合わせることにより、加入者は、グループに優先順位を付け、高いＳＩＮＲと良好なロードバランスの両方を実現することができる。

【００７６】

或る実施形態では、加入者は、エラー修正コードを使用することによってフィードバック情報を保護する。或る実施形態では、フィードバック内のＳＩＮＲ情報は、先ず、ソース符号化技術、例えば差分エンコーディングを使って圧縮され、次いでチャネルコードによってエンコードされる。

【００７７】

図８は、代表的なセルラーセットアップに関する周波数再使用パターンの或る実施形態を示している。各セルは、基地局で指向性アンテナを使用する６つのセクターを備えた六角形構造を有している。セル間では、周波数再使用係数は１である。各セル内では、周波数再使用係数は２であり、この場合、セクターは２つの周波数を交互に使用する。図８に示すように、影付きの各セクターは、利用可能なＯＦＤＭＡクラスタの半分を使用しており、影無しの各セクターは、クラスタの残り半分を使用している。一般性を損なわずに、影付きセクターに使用されているクラスタをここでは奇数クラスタと呼び、影無しのセクターに使用されているものをここでは偶数クラスタと呼ぶ。

【００７８】

加入者側での全方向アンテナによるダウンリンク信号送信を考察する。図８から、影付きセクターのダウンリンクに関して、セルＡはセルＢと干渉し、セルＢはセルＣと干渉し、セルＣはセルＡと干渉し、つまりＡ－＞Ｂ－＞Ｃ－＞Ａであることが明らかである。影無しセクターに関しては、セルＡはセルＣと干渉し、セルＣはセルＢと干渉し、セルＢはセルＡと干渉し、即ちＡ－＞Ｃ－＞Ｂ－＞Ａである　。

【００７９】

セクターＡ１は、セクターＣ１から干渉を受けるが、その送信は、セクターＢと干渉する。つまり、その干渉源と、それが干渉する被害者は同じではない。これは、干渉回避を使った分散クラスター割当システムに安定性の問題を発生させ、つまりは、周波数クラスタがセクターＣ１ではなくセクターＢ１に割り当てられた場合、そのクラスタは、ＡＩではクリーンに見えるためにＡ１に割り当てられる。しかしながら、このクラスタＡ１の割当により、Ｂ１の既存の割当に対する干渉問題が発生することになる。

【００８０】

或る実施形態では、トラフィックロードが累進的にセクターに加えられるときに上記問題を緩和するため、異なるクラスタグループには、異なるセルでの使用に関して異なる優先順位が割り当てられる。この優先順位は、クラスタを選択的に割り当てその干渉源からの干渉を回避すると共に、他のセルの既存の割当に対する干渉問題を引き起こす可能性を低減し、できれば最小化するように、統合的に規定される。

【００８１】

先に述べた例を使えば、奇数クラスタ（影付きセクターに使用される）は、３つのグルー

プ、グループ１、２、３に分割される。優先順位を表２に示す。

【００８２】

【表２】

表２：影付きセクターのダウンリンク用優先順位

優先順位	セルA	セルB	セルC
1	グループ1	グループ3	グループ2
2	グループ2	グループ1	グループ3
3	グループ3	グループ2	グループ1

【００８３】

セクターＡ１について考察する。最初に、グループ１のクラスタは、選択的に割り当てられる。クラスタを要求している加入者がまだもっとある場合、グループ２のクラスタが、測定されたＳＩＮＲによって、加入者に選択的に割り当てられる（セクターＣ１からの強い干渉を受けるクラスタを避ける）。なお、グループ２からセクターＡ１に新たに割り当てられたクラスタは、セクターＢ１のロードが非常に重くて、グループ３及び１双方のクラスタが使い果たされ、グループ２のクラスタも使用されている状態にならない限り、セクターＢ１で干渉問題を引き起こすことはない。表３は、全ての利用可能なクラスタの２／３より少ないクラスタがセクターＡ１、Ｂ１、及びＣ１で使用されている場合の、クラスタ使用を示している。

【００８４】

【表３】

表３：フルロードの２／３未満での、影付きセクターのダウンリンク用クラスタ使用

クラスタ使用	セルA	セルB	セルC
1	グループ1	グループ3	グループ2
2	グループ2	グループ1	グループ3
3			

【００８５】

図４は、影無しセクターの優先順位を示しているが、干渉関係が逆なので、影付きセクターの場合とは異なる。

【００８６】

【表４】

表４：影無しセクターのダウンリンク用優先順位

優先順位	セルA	セルB	セルC
1	グループ1	グループ2	グループ3
2	グループ2	グループ3	グループ1
3	グループ3	グループ1	グループ2

【００８７】

コヒーレンスクラスタとダイバーシティクラスタの間の知的切換

或る実施形態では、クラスタには２つのカテゴリ、即ち互いに接近している複数のサブキャリアを保有するコヒーレンスクラスタと、少なくとも一部がスペクトル全体に遙か離れて拡散しているサブキャリアを保有するダイバーシティクラスタがある。コヒーレンスクラスタ内の複数のサブキャリアの接近度は、チャネルコヒーレンス帯域幅内、即ち、チャ

ネル応答が概ね同じ帯域幅内、具体的には、多くのセルラーシステムでは通常１００ｋＨｚ以内、であるのが望ましい。これに対し、ダイバーシティクラスタ内のサブキャリアの拡散は、多くのセルラーシステムでは通常１００ｋＨｚ以内であるチャネルコヒーレンス帯域幅よりも広いのが望ましい。従って、このような場合の一般的な目標は拡散を最大化することである。

【００８８】

図９は、セルＡ－Ｃについてのコヒーレンスクラスタとダイバーシティクラスタの代表的クラスタフォーマットを示す。図９に示すように、セルＡ－Ｃに関し、周波数（サブキャリア）のラベリングは、周波数がコヒーレンスクラスタの一部であるかダイバーシティクラスタの一部であるかを示している。例えば、１－８のラベルが付いた周波数はダイバーシティクラスタであり、９－１６のラベルが付いたクラスタはコヒーレンスクラスタである。例えば、セル内のラベル１が付いた全ての周波数は、或るダーバーシティクラスタの一部であり、セル内のラベル２が付いた全ての周波数は、別のダイバーシティクラスタの一部であるが、一方ラベル９が付いた周波数のグループは１つのコヒーレンスクラスタであり、ラベル１０が付いた周波数のグループは別のコヒーレンスクラスタである、等となっている。ダイバーシティクラスタは、干渉平均化を介してセル間干渉の影響を低減するために、異なるセルに対し異なる構成とすることもできる。

【００８９】

図９は、３つの隣接するセルの一例的クラスタ構成を示している。１つのセル内の特定クラスタからの干渉は、他のセルの多くのクラスタに分配され、例えば、セルＡ内のクラスタ１からの干渉はセルＢ内のクラスタ１、８、７、６に分配される。これにより、セルＢ内のどの特定のクラスタに対しても干渉パワーが著しく低減されることになる。同様に、或るセル内のどの特定のクラスタに対する干渉も他のセル内の多くの異なるクラスタから来る。全てのクラスタが強い干渉を及ぼすわけではないので、サブキャリア全体に亘ってチャネル符号化を行うダイバーシティクラスタは、干渉ダイバーシティゲインを提供する。従って、セル境界に近く（例えば、コヒーレント帯域幅内）、セル間干渉を被り易い加入者には、ダイバーシティクラスタを割り当てるのが有効である。

【００９０】

コヒーレンスクラスタ内のサブキャリアは、互いに連続しているか接近している（例えば、コヒーレント帯域幅内）ので、チャネルフェージングのコヒーレント帯域幅内にある場合が多い。従って、コヒーレンスクラスタのチャネルゲインは、変動が大きく、クラスタ選択でその性能を大幅に改善することができる。一方、ダイバーシティクラスタの平均チャネルゲインは、スペクトルに亘って拡散する複数のサブキャリアの中でも本来的な周波数ダイバーシティの故に、バラツキの程度が小さい。クラスタ内のサブキャリア全体に亘ってチャネル符号化しているので、ダイバーシティクラスタは、（自身の多様化の性質上）クラスタの選択ミスに対しては強いが、クラスタ選択からのゲインは小さくなる。サブキャリア全体に亘るチャネル符号化とは、各コードワードが複数のサブキャリアから送信されたビットを含んでいることを意味し、より具体的には、コードワード間の差異ビット（エラーベクトル）が複数のサブキャリアの間に分配されることを意味している。

【００９１】

時間経過と共にサブキャリアホッピングを通してより多くの周波数ダイバーシティを得ることができ、加入者は、或るタイムスロットで或るサブキャリアのセットを占め、別のタイムスロットでは別の異なるサブキャリアのセットを占めることになる。１つの符号化単位（フレーム）は、このようなタイムスロットを複数保有しており、送信されたビットは全フレームに亘ってエンコードされる。

【００９２】

図１０は、サブキャリアホッピングを備えたダイバーシティクラスタを示す。図１０に示すように、図示のセルＡとセルＢには、それぞれ４つのダイバーシティクラスタがあり、個々のダイバーシティクラスタ内の各サブキャリアは、同一のラベル（１、２、３又は４）を有している。別個のタイムスロットを４つ示しているが、各タイムスロットの間に、

各ダイバーシティクラスタ用のサブキャリアは変化する。例えば、セルＡでは、サブキャリア１は、タイムスロット１の間はダイバーシティクラスタ１の一部であり、タイムスロット２の間はダイバーシティクラスタ２の一部であり、タイムスロット３の間はダイバーシティクラスタ３の一部であり、タイムスロット４の間はダイバーシティクラスタ４の一部である。この様に、時間経過に伴うサブキャリアホッピングを通して、より多くの干渉ダイバーシティを得ることができ、図１０に示すように、異なるセルに対し異なるホッピングパターンを使用することにより、更に多くの干渉ダイバーシティが実現できる。

【００９３】

加入者がサブキャリア（ホッピングシーケンス）を変更する方法は、符号化を通してより良好な干渉平均化を実現するために、セル毎に異なっていてもよい。

【００９４】

固定無線アクセスのような静止している加入者の場合、時間経過と共にチャネルが変わることは殆どない。コヒーレンスクラスタを使った選択的クラスタ割当は、良好な性能を実現する。一方、移動する加入者の場合、チャネル時間変動（時間経過に伴うチャネルの変化による変動）は非常に大きいこともある。ある時間に高ゲインのクラスタでも、別の時間には激しいフェージングに陥ることもありうる。従って、クラスタ割当は高速で更新しなければならず、制御オーバーヘッドが膨大になってしまう。この場合、ダイバーシティクラスタを使用すれば、強さを補強し、頻繁なクラスタ再割当のオーバーヘッドを軽減することができる。或る実施形態では、クラスタ割当は、しばしばチャネルドップラー速度（Ｈｚ）で計測されるチャネル変更速度、即ち、チャネルが１サイクル後には完全に異なる場合、チャネルが毎秒何サイクルで変更されるか、よりも高速で行なわれる。なお、選択的クラスタ割当は、コヒーレンスクラスタとダイバーシティクラスタの両方について行なうことができる。

【００９５】

或る実施形態では、移動する加入者と静止している加入者が入り混じっているセルの場合、加入者又は基地局、或いは両方に、チャネル／干渉変動検出器を実装することができる。検出結果を使って、加入者及び基地局は、セル境界線上の移動加入者又は静止加入者に対してはダイバーシティクラスタを、基地局に近い静止加入者に対してはコヒーレンスクラスタを、知的に選択する。チャネル／干渉変動検出器は、クラスタ毎に時々にチャネル（ＳＩＮＲ）変動を測定する。例えば、或る実施形態では、チャネル／干渉検出器は、各クラスタのパイロット記号の間のパワー差を測定し、移動ウインドウに亘る差を平均する（例えば、４つのタイムスロット）。差が大きければ、チャネル／干渉が頻繁に変化し、サブキャリア割当は信頼性が低いことを示している。そのような場合、その加入者にはダイバーシティクラスタがより望ましいことになる。

【００９６】

図１１は、加入者の移動に基づいてダイバーシティクラスタとコヒーレンスクラスタの間で知的選択を行うためのプロセスの或る実施形態のフロー図である。プロセスは、ハードウェア（例えば、回路、専用論理など）、ソフトウェア（例えば、汎用コンピュータシステム又は専用機械上で実行されるものなど）、又はその組合わせから成る処理論理によって行なわれる。

【００９７】

図１１に示すように、基地局の処理論理は、チャネル／干渉変動検出を行う（処理ブロック１１０１）。処理論理は、次に、チャネル／干渉変動検出の結果が、ユーザーが移動しているか又はセルの縁に近い静止位置にあることを示しているか否かをテストする（処理ブロック１１０２）。ユーザーが、移動していないか、セルの縁に近い静止位置にもいない場合、プロセスは処理ブロック１１０３に移り、そこで基地局の論理はコヒーレンスクラスタを選択し、それ以外の場合は、プロセスは処理ブロック１１０４に移り、そこで基地局の処理論理はダイバーシティクラスタを選択する。

【００９８】

選択は、再教育の間に更新し知的に切り替えることができる。

【００９９】
セル内のコヒーレンスクラスタとダイバーシティクラスタの数の比率／割当は、移動加入者と静止加入者の人数の比によって異なる。システムの展開に伴い人数が変わると、コヒーレンスクラスタとダイバーシティクラスタの割当は、新しいシステムの必要性を受け入れるため構成し直される。図１２は、図９よりも、もっと多くの移動する加入者をサポートできるクラスタ分類の再構成を示す。
【０１００】
当業者には、上記説明を読めば、本発明に多様な変更、修正を加え得ることが疑いも無く自明のものとなるはずであり、従って、説明を目的に図示し説明してきた具体的な実施形態は、全て、限定を意図していない旨理解頂きたい。従って、各種実施形態の詳細に関することは、本発明に不可欠と見なされる特性を詳述している特許請求の範囲に限定を加えることを意図したものではない。
【図面の簡単な説明】
【０１０１】
【図１Ａ】サブキャリアとクラスタを示す。
【図１Ｂ】サブキャリアを割り当てるプロセスの或る実施形態のフロー図である。
【図２】ＯＦＤＭ記号、パイロット、及びクラスタの時間と周波数グリッドを示す。
【図３】加入者の処理を示す。
【図４】図３の１例を示す。
【図５】任意クラスタフィードバック用のフォーマットの或る実施形態を示す。
【図６】クラスタをグループに分割する或る実施形態を示す。
【図７】グループベースのクラスタ割当のためのフィードバックフォーマットの或る実施形態を示す。
【図８】多重セル多重セクターネットワークにおける周波数再利用と干渉を示す。
【図９】コヒーレンスクラスタとダイバーシティクラスタ用の別々のクラスタフォーマットを示す。
【図１０】サブキャリアホッピングを有するダイバーシティクラスタを示す。
【図１１】加入者の移動による、ダイバーシティクラスタとコヒーレンスクラスタの間の知的切り替えを示す。
【図１２】クラスタ分類の再構成の或る実施形態を示す。
【図１３】基地局の或る実施形態を示す。

【図１Ａ】

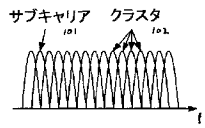


Figure 1A

【図１Ｂ】

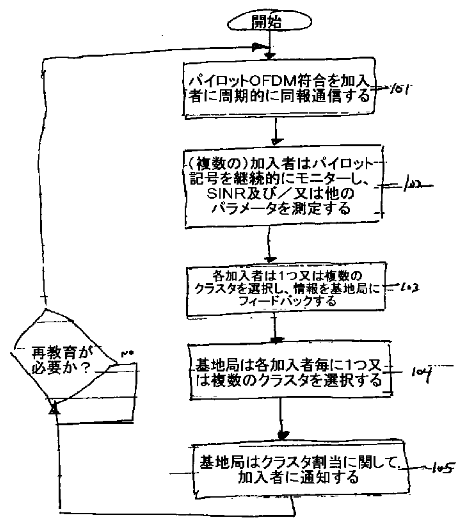


Figure 1B

【図２】

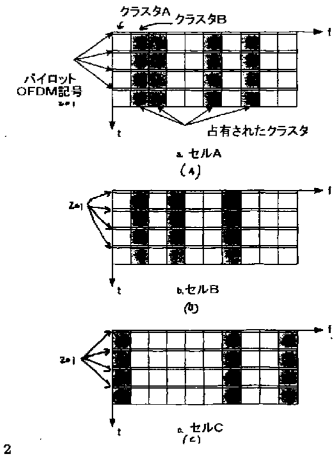


Figure 2

【図３】

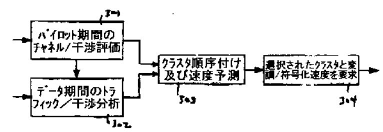


Figure 3

【図４】

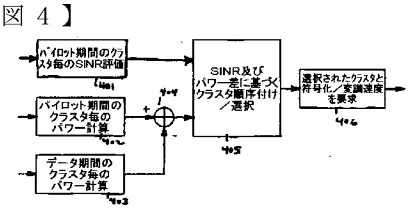


Figure 4

【図５】

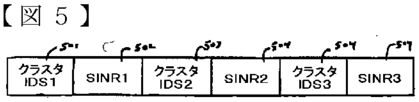


Figure 5

【図６】

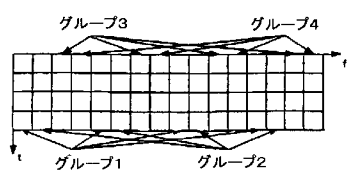


Figure 6

【図７】

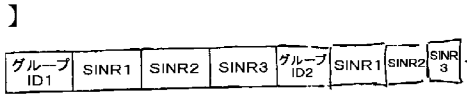


Figure 7

【図９】

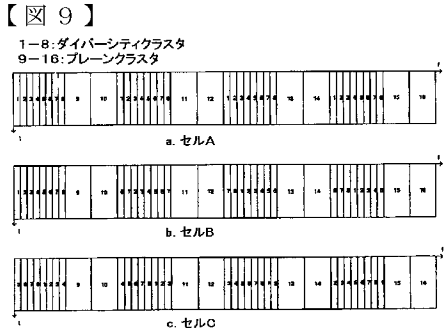


Figure 9

【図１０】

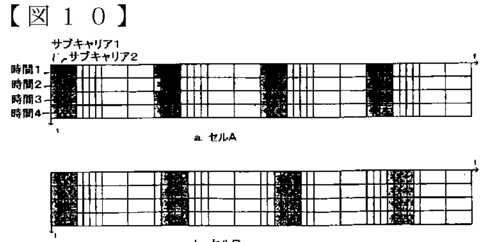


Figure 10

【図１１】

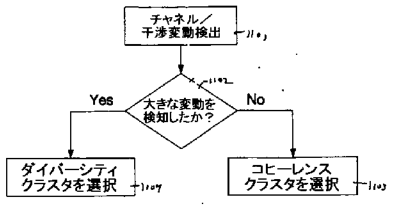


Figure 11

【図１２】

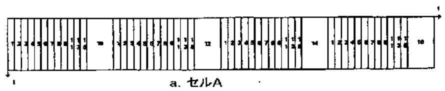
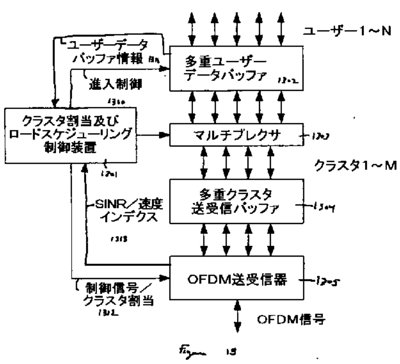


Figure 12

【図１３】



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(54) Title: OFDMA WITH ADAPTIVE SUBCARRIER-CLUSTER CONFIGURATION AND SELECTIVE LOADING

(57) **Abstract:** A method and apparatus for subcarrier selection for systems is described. In one embodiment, the system employs orthogonal frequency division multiple access (OFDMA). In one embodiment, a method for subcarrier selection compreses each of multiple subscribes measuring channel and interference information for subcarriers based on pilot symbols received from a base station, at least one of subscribers selecting a set of candidate subcarriers, providing feedback information on the set of candidate subcarriers to the base station, andthe one subscriber receiving an indicaiton of subcarriers to the base station, and the one subscriber receiving an indication of subcarriers of the set of subcarriers selected bz the base station for use by the one subscriber.

OFDMA WITH ADAPTIVE SUBCARRIER-CLUSTER CONFIGURATION AND SELECTIVE LOADING

FIELD OF THE INVENTION

The invention relates to the field of wireless communications; more particularly, the invention relates to multi-cell, multi-subscriber wireless systems using orthogonal frequency division multiplexing (OFDM).

BACKGROUND OF THE INVENTION

Orthogonal frequency division multiplexing (OFDM) is an efficient modulation scheme for signal transmission over frequency-selective channels. In OFDM, a wide bandwidth is divided into multiple narrow-band subcarriers, which are arranged to be orthogonal with each other. The signals modulated on the subcarriers are transmitted in parallel. For more information, see Cimini, Jr., "Analysis and Simulation of a Digital Mobile Channel Using Orthogonal Frequency Division Multiplexing," IEEE Trans. Commun., vol. COM-33, no. 7, July 1985, pp. 665-75; Chuang and Sollenberger, "Beyond 3G: Wideband Wireless Data Access Based on OFDM and Dynamic Packet Assignment," IEEE Communications Magazine, Vol. 38, No. 7, pp. 78–87, July 2000.

One way to use OFDM to support multiple access for multiple subscribers is through time division multiple access (TDMA), in which each subscriber uses all the subcarriers within its assigned time slots. Orthogonal frequency division multiple access (OFDMA) is another method for multiple access, using the basic format of OFDM. In OFDMA, multiple subscribers simultaneously use different subcarriers, in a fashion similar to frequency division multiple access (FDMA). For more information, see Sari and Karam, "Orthogonal Frequency-Division Multiple Access and its Application to CATV Networks," European Transactions on Telecommunications, Vol. 9 (6), pp. 507-516, Nov./Dec. 1998 and Nogueroles, Bossert, Donder, and Zyablov, "Improved Performance of a Random OFDMA Mobile Communication System,", Proceedings of IEEE VTC'98, pp. 2502 –2506.

Multipath causes frequency-selective fading. The channel gains are different for different subcarriers. Furthermore, the channels are typically uncorrelated for different subscribers. The subcarriers that are in deep fade for one subscriber may provide high channel gains for another subscriber. Therefore, it is advantageous in an OFDMA

system to adaptively allocate the subcarriers to subscribers so that each subscriber enjoys a high channel gain. For more information, see Wong et al., "Multiuser OFDM with Adaptive Subcarrier, Bit and Power Allocation," IEEE J. Select. Areas Commun., Vol. 17(10), pp. 1747-1758, October 1999.

Within one cell, the subscribers can be coordinated to have different subcarriers in OFDMA. The signals for different subscribers can be made orthogonal and there is little intracell interference. However, with aggressive frequency reuse plan, e.g., the same spectrum is used for multiple neighboring cells, the problem of intercell interference arises. It is clear that the intercell interference in an OFDMA system is also frequency selective and it is advantageous to adaptively allocate the subcarriers so as to mitigate the effect of intercell interference.

One approach to subcarrier allocation for OFDMA is a joint optimization operation, not only requiring the activity and channel knowledge of all the subscribers in all the cells, but also requiring frequent rescheduling every time an existing subscribers is dropped off the network or a new subscribers is added onto the network. This is often impractical in real wireless system, mainly due to the bandwidth cost for updating the subscriber information and the computation cost for the joint optimization.

SUMMARY OF THE INVENTION

A method and apparatus for subcarrier selection for systems is described. In one embodiment, the system employs orthogonal frequency division multiple access (OFDMA). In one embodiment, a method for subcarrier selection comprises a subscriber measuring channel and interference information for subcarriers based on pilot symbols received from a base station, the subscriber selecting a set of candidate subcarriers, providing feedback information on the set of candidate subcarriers to the base station, and receiving an indication of subcarriers of the set of subcarriers selected by the base station for use by the subscriber.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be understood more fully from the detailed description given below and from the accompanying drawings of various embodiments of the invention, which, however, should not be taken to limit the invention to the specific embodiments, but are for explanation and understanding only.

Figure 1A illustrates subcarriers and clusters.

Figure 1B is a flow diagram of one embodiment of a process for allocating subcarriers.

Figure 2 illustrates time and frequency grid of OFDM symbols, pilots and clusters.

Figure 3 illustrates subscriber processing.

Figure 4 illustrates one example of Figure 3.

Figure 5 illustrates one embodiment of a format for arbitrary cluster feedback.

Figure 6 illustrates one embodiment of a partition the clusters into groups.

Figure 7 illustrates one embodiment of a feedback format for group-based cluster allocation.

Figure 8 illustrates frequency reuse and interference in a multi-cell, multi-sector network.

Figure 9 illustrates different cluster formats for coherence clusters and diversity clusters.

Figure 10 illustrates diversity clusters with subcarrier hopping.

Figure 11 illustrates intelligent switching between diversity clusters and coherence clusters depending on subscribers mobility.

Figure 12 illustrates one embodiment of a reconfiguration of cluster classification.

Figure 13 illustrates one embodiment of a base station.

DETAILED DESCRIPTION OF THE PRESENT INVENTION

A distributed, reduced-complexity approach for subcarrier allocation is described. The techniques disclosed herein are described using OFDMA (clusters) as an example. However, they are not limited to OFDMA-based systems. The techniques apply to multi-carrier systems in general, where, for example, a carrier can be a cluster in OFDMA, a spreading code in CDMA, an antenna beam in SDMA (space-division multiple access), etc. In one embodiment, subcarrier allocation is performed in each cell separately. Within each cell, the allocation for individual subscribers (e.g., mobiles) is also made progressively as each new subscriber is added to the system as opposed to joint allocation for subscribers within each cell in which allocation decisions are made taking into account all subscribers in a cell for each allocation.

For downlink channels, each subscriber first measures the channel and interference information for all the subcarriers and then selects multiple subcarriers with good performance (e.g., a high signal-to-interference plus noise ratio (SINR)) and feeds back the information on these candidate subcarriers to the base station. The feedback may comprise channel and interference information (e.g., signal-to-interference-plus-noise-ratio information) on all subcarriers or just a portion of subcarriers. In case of providing information on only a portion of the subcarriers, a subscriber may provide a list of subcarriers ordered starting with those subcarriers which the subscriber desires to use, usually because their performance is good or better than that of other subcarriers.

Upon receiving the information from the subscriber, the base station further selects the subcarriers among the candidates, utilizing additional information available at the base station, e.g., the traffic load information on each subcarrier, amount of traffic requests queued at the base station for each frequency band, whether frequency bands are overused, and/or how long a subscriber has been waiting to send information. In one embodiment, the subcarrier loading information of neighboring cells can also be exchanged between base stations. The base stations can use this information in subcarrier allocation to reduce inter-cell interference.

In one embodiment, the selection by the base station of the channels to allocate, based on the feedback, results in the selection of coding/modulation rates. Such coding/modulation rates may be specified by the subscriber when specifying subcarriers that it finds favorable to use. For example, if the SINR is less than a certain threshold (e.g., 12 dB), quadrature phase shift keying (QPSK) modulation is used; otherwise, 16 quadrature amplitude modulation (QAM) is used. Then the base station informs the subscribers about the subcarrier allocation and the coding/modulation rates to use.

In one embodiment, the feedback information for downlink subcarrier allocation is transmitted to the base station through the uplink access channel, which occurs in a short period every transmission time slot, e.g., 400 microseconds in every 10-millisecond time slot. In one embodiment, the access channel occupies the entire frequency bandwidth. Then the base station can collect the uplink SINR of each subcarrier directly from the access channel. The SINR as well as the traffic load information on the uplink subcarriers are used for uplink subcarrier allocation.

For either direction, the base station makes the final decision of subcarrier allocation for each subscriber.

In the following description, a procedure of selective subcarrier allocation is also disclosed, including methods of channel and interference sensing, methods of information feedback from the subscribers to the base station, and algorithms used by the base station for subcarrier selections.

In the following description, numerous details are set forth to provide a thorough understanding of the present invention. It will be apparent, however, to one skilled in the art, that the present invention may be practiced without these specific details. In other instances, well-known structures and devices are shown in block diagram form, rather than in detail, in order to avoid obscuring the present invention.

Some portions of the detailed descriptions which follow are presented in terms of algorithms and symbolic representations of operations on data bits within a computer memory. These algorithmic descriptions and representations are the means used by those skilled in the data processing arts to most effectively convey the substance of their work to others skilled in the art. An algorithm is here, and generally, conceived to be a self-consistent sequence of steps leading to a desired result. The steps are those requiring physical manipulations of physical quantities. Usually, though not necessarily, these quantities take the form of electrical or magnetic signals capable of being stored, transferred, combined, compared, and otherwise manipulated. It has proven convenient at times, principally for reasons of common usage, to refer to these signals as bits, values, elements, symbols, characters, terms, numbers, or the like.

It should be borne in mind, however, that all of these and similar terms are to be associated with the appropriate physical quantities and are merely convenient labels applied to these quantities. Unless specifically stated otherwise as apparent from the following discussion, it is appreciated that throughout the description, discussions utilizing terms such as "processing" or "computing" or "calculating" or "determining" or "displaying" or the like, refer to the action and processes of a computer system, or similar electronic computing device, that manipulates and transforms data represented as physical (electronic) quantities within the computer system's registers and memories into other data similarly represented as physical quantities within the computer system memories or registers or other such information storage, transmission or display devices.

The present invention also relates to apparatus for performing the operations herein. This apparatus may be specially constructed for the required purposes, or it may comprise a general purpose computer selectively activated or reconfigured by a computer

program stored in the computer. Such a computer program may be stored in a computer readable storage medium, such as, but is not limited to, any type of disk including floppy disks, optical disks, CD-ROMs, and magnetic-optical disks, read-only memories (ROMs), random access memories (RAMs), EPROMs, EEPROMs, magnetic or optical cards, or any type of media suitable for storing electronic instructions, and each coupled to a computer system bus.

The algorithms and displays presented herein are not inherently related to any particular computer or other apparatus. Various general purpose systems may be used with programs in accordance with the teachings herein, or it may prove convenient to construct more specialized apparatus to perform the required method steps. The required structure for a variety of these systems will appear from the description below. In addition, the present invention is not described with reference to any particular programming language. It will be appreciated that a variety of programming languages may be used to implement the teachings of the invention as described herein.

A machine-readable medium includes any mechanism for storing or transmitting information in a form readable by a machine (e.g., a computer). For example, a machine-readable medium includes read only memory ("ROM"); random access memory ("RAM"); magnetic disk storage media; optical storage media; flash memory devices; electrical, optical, acoustical or other form of propagated signals (e.g., carrier waves, infrared signals, digital signals, etc.); etc.

Subcarrier Clustering

The techniques described herein are directed to subcarrier allocation for data traffic channels. In a cellular system, there are typically other channels, pre-allocated for the exchange of control information and other purposes. These channels often include down link and up link control channels, uplink access channels, and time and frequency synchronization channels.

Figure 1A illustrates multiple subcarriers, such as subcarrier 101, and cluster 102. A cluster, such as cluster 102, is defined as a logical unit that contains at least one physical subcarrier, as shown in Figure 1A. A cluster can contain consecutive or disjoint subcarriers. The mapping between a cluster and its subcarriers can be fixed or reconfigurable. In the latter case, the base station informs the subscribers when the clusters are redefined. In one embodiment, the frequency spectrum includes 512

subcarriers and each cluster includes four consecutive subcarriers, thereby resulting in 128 clusters.

An Exemplary Subcarrier/Cluster Allocation Procedure

Figure 1B is a flow diagram of one embodiment of a process for allocation clusters to subscribers. The process is performed by processing logic that may comprise hardware (e.g., dedicated logic, circuitry, etc.), software (such as that which runs on, for example, a general purpose computer system or dedicated machine), or a combination of both.

Referring to Figure 1B, each base station periodically broadcasts pilot OFDM symbols to every subscriber within its cell (or sector) (processing block 101). The pilot symbols, often referred to as a sounding sequence or signal, are known to both the base station and the subscribers. In one embodiment, each pilot symbol covers the entire OFDM frequency bandwidth. The pilot symbols may be different for different cells (or sectors). The pilot symbols can serve multiple purposes: time and frequency synchronization, channel estimation and signal-to-interference/noise (SINR) ratio measurement for cluster allocation.

Next, each subscriber continuously monitors the reception of the pilot symbols and measures the SINR and/or other parameters, including inter-cell interference and intra-cell traffic, of each cluster (processing block 102). Based on this information, each subscriber selects one or more clusters with good performance (e.g., high SINR and low traffic loading) relative to each other and feeds back the information on these candidate clusters to the base station through predefined uplink access channels (processing block 103). For example, SINR values higher than 10 dB may indicate good performance. Likewise, a cluster utilization factor less than 50% may be indicative of good performance. Each subscriber selects the clusters with relatively better performance than others. The selection results in each subscriber selecting clusters they would prefer to use based on the measured parameters.

In one embodiment, each subscriber measures the SINR of each subcarrier cluster and reports these SINR measurements to their base station through an access channel. The SINR value may comprise the average of the SINR values of each of the subcarriers in the cluster. Alternatively, the SINR value for the cluster may be the worst SINR among the SINR values of the subcarriers in the cluster. In still another embodiment, a

weighted averaging of SINR values of the subcarriers in the cluster is used to generate an SINR value for the cluster. This may be particularly useful in diversity clusters where the weighting applied to the subcarriers may be different.

The feedback of information from each subscriber to the base station contains a SINR value for each cluster and also indicates the coding/modulation rate that the subscriber desires to use. No cluster index is needed to indicate which SINR value in the feedback corresponds to which cluster as long as the order of information in the feedback is known to the base station. In an alternative embodiment, the information in the feedback is ordered according to which clusters have the best performance relative to each other for the subscriber. In such a case, an index is needed to indicate to which cluster the accompanying SINR value corresponds.

Upon receiving the feedback from a subscriber, the base station further selects one or more clusters for the subscriber among the candidates (processing block 104). The base station may utilize additional information available at the base station, e.g., the traffic load information on each subcarrier, amount of traffic requests queued at the base station for each frequency band, whether frequency bands are overused, and how long a subscriber has been waiting to send information. The subcarrier loading information of neighboring cells can also be exchanged between base stations. The base stations can use this information in subcarrier allocation to reduce inter-cell interference.

After cluster selection, the base station notifies the subscriber about the cluster allocation through a downlink common control channel or through a dedicated downlink traffic channel if the connection to the subscriber has already been established (processing block 105). In one embodiment, the base station also informs the subscriber about the appropriate modulation/coding rates.

Once the basic communication link is established, each subscriber can continue to send the feedback to the base station using a dedicated traffic channel (e.g., one or more predefined uplink access channels).

In one embodiment, the base station allocates all the clusters to be used by a subscriber at once. In an alternative embodiment, the base station first allocates multiple clusters, referred to herein as the basic clusters, to establish a data link between the base station and the subscriber. The base station then subsequently allocates more clusters, referred to herein as the auxiliary clusters, to the subscriber to increase the communication bandwidth. Higher priorities can be given to the assignment of basic

clusters and lower priorities may be given to that of auxiliary clusters. For example, the base station first ensures the assignment of the basic clusters to the subscribers and then tries to satisfy further requests on the auxiliary clusters from the subscribers. Alternatively, the base station may assign auxiliary clusters to one or more subscribers before allocating basic clusters to other subscribers. For example, a base station may allocate basic and auxiliary clusters to one subscriber before allocating any clusters to other subscribers. In one embodiment, the base station allocates basic clusters to a new subscriber and then determines if there are any other subscribers requesting clusters. If not, then the base station allocates the auxiliary clusters to that new subscriber.

From time to time, processing logic performs retraining by repeating the process described above (processing block 106). The retraining may be performed periodically. This retraining compensates for subscriber movement and any changes in interference. In one embodiment, each subscriber reports to the base station its updated selection of clusters and their associated SINRs. Then the base station further performs the reselection and informs the subscriber about the new cluster allocation. Retraining can be initiated by the base station, and in which case, the base station requests a specific subscriber to report its updated cluster selection. Retraining can also be initiated by the subscriber when it observes channel deterioration.

Adaptive Modulation and Coding

In one embodiment, different modulation and coding rates are used to support reliable transmission over channels with different SINR. Signal spreading over multiple subcarriers may also be used to improve the reliability at very low SINR.

An example coding/modulation table is given below in Table 1.

Table 1

Scheme	Modulation	Code Rate
0	QPSK,1/8 Spreading	½
1	QPSK,¼ Spreading	½
2	QPSK,½ Spreading	½
3	QPSK	½
4	8PSK	2/3
5	16QAM	3/4
6	64QAM	5/6

In the example above, 1/8 spreading indicates that one QPSK modulation symbol is repeated over eight subcarriers. The repetition/spreading may also be extended to the time domain. For example, one QPSK symbol can be repeated over four subcarriers of two OFDM symbols, resulting also 1/8 spreading.

The coding/modulation rate can be adaptively changed according to the channel conditions observed at the receiver after the initial cluster allocation and rate selection.

Pilot Symbols and SINR Measurement

In one embodiment, each base station transmits pilot symbols simultaneously, and each pilot symbol occupies the entire OFDM frequency bandwidth, as shown in Figures 2A-C. Referring to Figure 2A-C, pilot symbols 201 are shown traversing the entire OFDM frequency bandwidth for cells A, B and C, respectively. In one embodiment, each of the pilot symbols have a length or duration of 128 microseconds with a guard time, the combination of which is approximately 152 microseconds. After each pilot period, there are a predetermined number of data periods followed by another set of pilot symbols. In one embodiment, there are four data periods used to transmit data after each pilot, and each of the data periods is 152 microseconds.

A subscriber estimates the SINR for each cluster from the pilot symbols. In one embodiment, the subscriber first estimates the channel response, including the amplitude and phase, as if there is no interference or noise. Once the channel is estimated, the subscriber calculates the interference/noise from the received signal.

The estimated SINR values may be ordered from largest to smallest SINRs and the clusters with large SINR values are selected. In one embodiment, the selected

clusters have SINR values that are larger than the minimum SINR which still allows a reliable (albeit low-rate) transmission supported by the system. The number of clusters selected may depend on the feedback bandwidth and the request transmission rate. In one embodiment, the subscriber always tries to send the information about as many clusters as possible from which the base station chooses.

The estimated SINR values are also used to choose the appropriate coding/modulation rate for each cluster as discussed above. By using an appropriate SINR indexing scheme, an SINR index may also indicate a particular coding and modulation rate that a subscriber desires to use. Note that even for the same subscribers, different clusters can have different modulation/coding rates.

Pilot symbols serve an additional purpose in determining interference among the cells. Since the pilots of multiple cells are broadcast at the same time, they will interfere with each other (because they occupy the entire frequency band). This collision of pilot symbols may be used to determine the amount of interference as a worst case scenario. Therefore, in one embodiment, the above SINR estimation using this method is conservative in that the measured interference level is the worst-case scenario, assuming that all the interference sources are on. Thus, the structure of pilot symbols is such that it occupies the entire frequency band and causes collisions among different cells for use in detecting the worst case SINR in packet transmission systems.

During data traffic periods, the subscribers can determine the level of interference again. The data traffic periods are used to estimate the intra-cell traffic as well as the inter-cell interference level. Specifically, the power difference during the pilot and traffic periods may be used to sense the (intra-cell) traffic loading and inter-cell interference to select the desirable clusters.

The interference level on certain clusters may be lower, because these clusters may be unused in the neighboring cells. For example, in cell A, with respect to cluster A there is less interference because cluster A is unused in cell B (while it is used in cell C). Similarly, in cell A, cluster B will experience lower interference from cell B because cluster B is used in cell B but not in cell C.

The modulation/coding rate based on this estimation is robust to frequent interference changes resulted from bursty packet transmission. This is because the rate prediction is based on the worst case situation in which all interference sources are transmitting.

In one embodiment, a subscriber utilizes the information available from both the pilot symbol periods and the data traffic periods to analyze the presence of both the intra-cell traffic load and inter-cell interference. The goal of the subscriber is to provide an indication to the base station as to those clusters that the subscriber desires to use. Ideally, the result of the selection by the subscriber is clusters with high channel gain, low interference from other cells, and high availability. The subscriber provides feedback information that includes the results, listing desired clusters in order or not as described herein.

Figure 3 illustrates one embodiment of subscriber processing. The processing is performed by processing logic that may comprise hardware (e.g., dedicated logic, circuitry, etc.), software (such as that which runs on, for example, a general purpose computer system or dedicated machine), or a combination of both.

Referring to Figure 3, channel/interference estimation processing block 301 performs channel and interference estimation in pilot periods in response to pilot symbols. Traffic/interference analysis processing block 302 performs traffic and interference analysis in data periods in response to signal information and information from channel/interference estimation block 301.

Cluster ordering and rate prediction processing block 303 is coupled to outputs of channel/interference estimation processing block 301 and traffic/interference analysis processing block 302 to perform cluster ordering and selection along with rate prediction.

The output of cluster ordering processing block 303 is input to cluster request processing block 304, which requests clusters and modulation/coding rates. Indications of these selections are sent to the base station. In one embodiment, the SINR on each cluster is reported to the base station through an access channel. The information is used for cluster selection to avoid clusters with heavy intra-cell traffic loading and/or strong interference from other cells. That is, a new subscriber may not be allocated use of a particular cluster if heavy intra-cell traffic loading already exists with respect to that cluster. Also, clusters may not be allocated if the interference is so strong that the SINR only allows for low-rate transmission or no reliable transmission at all.

The channel/interference estimation by processing block 301 is well-known in the art by monitoring the interference that is generated due to full-bandwidth pilot symbols being simultaneously broadcast in multiple cells. The interface information is

forwarded to processing block 302 which uses the information to solve the following equation:

$$H_i S_i + I_i + n_i = y_i$$

where S_i represents the signal for subcarrier (freq. band) i, I_i is the interference for subcarrier i, n_i is the noise associated with subcarrier i, and y_i is the observation for subcarrier i. In the case of 512 subcarriers, i may range from 0 to 511. The I_i and n_i are not separated and may be considered one quantity. The interference/noise and channel gain H_i are not know. During pilot periods, the signal S_i representing the pilot symbols, and the observation y_i are knowns, thereby allowing determination of the channel gain H_i for the case where there is no interference or noise. Once this is known, it may be plugged back into the equation to determine the interference/noise during data periods since H_i, S_i and y_i are all known.

The interference information from processing blocks 301 and 302 are used by the subscriber to select desirable clusters. In one embodiment, using processing block 303, the subscriber orders clusters and also predicts the data rate that would be available using such clusters. The predicted data rate information may be obtained from a look up table with precalculated data rate values. Such a look up table may store the pairs of each SINR and its associated desirable transmission rate. Based on this information, the subscriber selects clusters that it desires to use based on predetermined performance criteria. Using the ordered list of clusters, the subscriber requests the desired clusters along with coding and modulation rates known to the subscriber to achieve desired data rates.

Figure 4 is one embodiment of an apparatus for the selection of clusters based on power difference. The approach uses information available during both pilot symbol periods and data traffic periods to perform energy detection. The processing of Figure 4 may be implemented in hardware, (e.g., dedicated logic, circuitry, etc.), software (such as is run on, for example, a general purpose computer system or dedicated machine), or a combination of both.

Referring to Figure 4, a subscriber includes SINR estimation processing block 401 to perform SINR estimation for each cluster in pilot periods, power calculation processing block 402 to perform power calculations for each cluster in pilot periods, and

power calculation processing block 403 to perform power calculations in data periods for each cluster. Subtractor 404 subtracts the power calculations for data periods from processing block 403 from those in pilot periods from processing block 402. The output of subtractor 404 is input to power difference ordering (and group selection) processing block 405 that performs cluster ordering and selection based on SINR and the power difference between pilot periods and data periods. Once the clusters have been selected, the subscriber requests the selected clusters and the coding/modulation rates with processing block 406.

More specifically, in one embodiment, the signal power of each cluster during the pilot periods is compared with that during the traffic periods, according to the following:

$$P_P = P_S + P_I + P_N,$$

$$P_D = \begin{cases} P_N, \text{ with no signal and interference} \\ P_S + P_N, \text{ with signal only} \\ P_I + P_N, \text{ with interference only} \\ P_S + P_I + P_N, \text{ with both signal and interference} \end{cases}$$

$$P_P - P_D = \begin{cases} P_S + P_I, \text{ with no signal and interference} \\ P_I, \text{ with signal only} \\ P_S, \text{ with interference only} \\ 0, \text{ with both signal and interference} \end{cases}$$

where P_P is the measured power corresponding to each cluster during pilot periods, P_D is the measured power during the traffic periods, P_S is the signal power, P_I is the interference power, and P_N is the noise power.

In one embodiment, the subscriber selects clusters with relatively large $P_p/(P_P - P_D)$ (e.g., larger than a threshold such as 10dB) and avoids clusters with low $P_p/(P_P - P_D)$ (e.g., lower than a threshold such as 10dB) when possible.

Alternatively, the difference may be based on the energy difference between observed samples during the pilot period and during the data traffic period for each of the subcarriers in a cluster such as the following:

$$\Delta_i = |y_i^F| - |y_i^D|$$

Thus, the subscriber sums the differences for all subcarriers.

Depending on the actual implementation, a subscriber may use the following metric, a combined function of both SINR and $P_P - P_D$, to select the clusters:

$$\beta = f(\text{SINR}, P_P /(P_P - P_D))$$

where f is a function of the two inputs. One example of f is weighted averaging (e.g., equal weights). Alternatively, a subscriber selects a cluster based on its SINR and only uses the power difference $P_P - P_D$ to distinguish clusters with similar SINR. The difference may be smaller than a threshold (e.g., 1 dB).

Both the measurement of SINR and $P_P - P_D$ can be averaged over time to reduce variance and improve accuracy. In one embodiment, a moving-average time window is used that is long enough to average out the statistical abnormity yet short enough to capture the time-varying nature of channel and interference, e.g., 1 millisecond.

Feedback Format for Downlink Cluster Allocation

In one embodiment, for the downlink, the feedback contains both the indices of selected clusters and their SINR. An exemplary format for arbitrary cluster feedback is shown in Figure 5. Referring to Figure 5, the subscriber provides a cluster index (ID) to indicate the cluster and its associated SINR value. For example, in the feedback, the subscriber provides cluster ID1 (501) and the SINR for the cluster, SINR1 (502), cluster ID2 (503) and the SINR for the cluster, SINR2 (504), and cluster ID3 (505), and the SINR for the cluster, SINR3 (506), etc. The SINR for the cluster may be created using an average of the SINRs of the subcarriers. Thus, multiple arbitrary clusters can be selected as the candidates. As discussed above, the selected clusters can also be ordered in the feedback to indicate priority. In one embodiment, the subscriber may form a priority list of clusters and sends back the SINR information in a descending order of priority.

Typically, an index to the SINR level, instead of the SINR itself is sufficient to indicate the appropriate coding/modulation for the cluster. For example, a 3-bit field can be used for SINR indexing to indicate 8 different rates of adaptive coding/modulation.

An Exemplary Base Station

The base station assigns desirable clusters to the subscriber making the request. In one embodiment, the availability of the cluster for allocation to a subscriber depends on the total traffic load on the cluster. Therefore, the base station selects the clusters not only with high SINR, but also with low traffic load.

Figure 13 is a block diagram of one embodiment of a base station. Referring to Figure 13, cluster allocation and load scheduling controller 1301 (cluster allocator) collects all the necessary information, including the downlink/uplink SINR of clusters specified for each subscriber (e.g., via SINR/rate indices signals 1313 received from OFDM transceiver 1305) and user data, queue fullness/traffic load (e.g., via user data buffer information 1311 from multi-user data buffer 1302). Using this information, controller 1301 makes the decision on cluster allocation and load scheduling for each user, and stores the decision information in a memory (not shown). Controller 1301 informs the subscribers about the decisions through control signal channels (e.g., control signal/cluster allocation 1312 via OFDM transceiver 1305). Controller 1301 updates the decisions during retraining.

In one embodiment, controller 1301 also performs admission control to user access since it knows the traffic load of the system. This may be performed by controlling user data buffers 1302 using admission control signals 1310.

The packet data of User 1 ~ N are stored in the user data buffers 1302. For downlink, with the control of controller 1301, multiplexer 1303 loads the user data to cluster data buffers (for Cluster 1 ~ M) waiting to be transmitted. For the uplink, multiplexer 1303 sends the data in the cluster buffers to the corresponding user buffers. Cluster buffer 1304 stores the signal to be transmitted through OFDM transceiver 1305 (for downlink) and the signal received from transceiver 1305. In one embodiment, each user might occupy multiple clusters and each cluster might be shared by multiple users (in a time-division-multiplexing fashion).

Group-Based Cluster Allocation

In another embodiment, for the downlink, the clusters are partitioned into groups. Each group can include multiple clusters. Figure 6 illustrates an exemplary partitioning. Referring to Figure 6, groups 1-4 are shown with arrows pointing to clusters that are in each group as a result of the partitioning. In one embodiment, the clusters within each group are spaced far apart over the entire bandwidth. In one embodiment, the clusters

within each group are spaced apart farther than the channel coherence bandwidth, i.e. the bandwidth within which the channel response remains roughly the same. A typical value of coherence bandwidth is 100 kHz for many cellular systems. This improves frequency diversity within each group and increases the probability that at least some of the clusters within a group can provide high SINR. The clusters may be allocated in groups. Goals of group-based cluster allocation include reducing the data bits for cluster indexing, thereby reducing the bandwidth requirements of the feedback channel (information) and control channel (information) for cluster allocation. Group-based cluster allocation may also be used to reduce inter-cell interference.

After receiving the pilot signal from the base station, a subscriber sends back the channel information on one or more cluster groups, simultaneously or sequentially. In one embodiment, only the information on some of the groups is sent back to the base station. Many criteria can be used to choose and order the groups, based on the channel information, the inter-cell interference levels, and the intra-cell traffic load on each cluster.

In one embodiment, a subscriber first selects the group with the best overall performance and then feedbacks the SINR information for the clusters in that group. The subscriber may order the groups based on their number of clusters for which the SINR is higher than a predefined threshold. By transmitting the SINR of all the clusters in the group sequentially, only the group index, instead of all the cluster indices, needs to be transmitted. Thus, the feedback for each group generally contains two types of information: the group index and the SINR value of each cluster within the group. Figure 7 illustrates an exemplary format for indicating a group-based cluster allocation. Referring to Figure 7, a group ID, ID1, is followed by the SINR values for each of the clusters in the group. This can significantly reduce the feedback overhead.

Upon receiving the feedback information from the subscriber, the cluster allocator at the base station selects multiple clusters from one or more groups, if available, and then assigns the clusters to the subscriber. This selection may be performed by an allocation in a media access control portion of the base station.

Furthermore, in a multi-cell environment, groups can have different priorities associated with different cells. In one embodiment, the subscriber's selection of a group is biased by the group priority, which means that certain subscribers have higher priorities on the usage of some groups than the other subscribers.

In one embodiment, there is no fixed association between one subscriber and one cluster group; however, in an alternative embodiment there may be such a fixed association. In an implementation having a fixed association between a subscriber and one or more cluster groups, the group index in the feedback information can be omitted, because this information is known to both subscriber and base station by default.

In another embodiment, the pilot signal sent from the base station to the subscriber also indicates the availability of each cluster, e.g., the pilot signal shows which clusters have already been allocated for other subscribers and which clusters are available for new allocations. For example, the base station can transmit a pilot sequence 1111 1111 on the subcarriers of a cluster to indicate that the cluster is available, and 1111 -1-1-1-1 to indicate the cluster is not available. At the receiver, the subscriber first distinguishes the two sequences using the signal processing methods which are well known in the art, e.g., the correlation methods, and then estimates the channel and interference level.

With the combination of this information and the channel characteristics obtained by the subscriber, the subscriber can prioritize the groups to achieve both high SINR and good load balancing.

In one embodiment, the subscriber protects the feedback information by using error correcting codes. In one embodiment, the SINR information in the feedback is first compressed using source coding techniques, e.g., differential encoding, and then encoded by the channel codes.

Figure 8 shows one embodiment of a frequency reuse pattern for an exemplary cellular set up. Each cell has hexagonal structure with six sectors using directional antennas at the base stations. Between the cells, the frequency reuse factor is one. Within each cell, the frequency reuse factor is 2 where the sectors use two frequencies alternatively. As shown in Figure 8, each shaded sector uses half of the available OFDMA clusters and each unshaded sector uses the other half of the clusters. Without loss of generality, the clusters used by the shaded sectors are referred to herein as odd clusters and those used by the unshaded sectors are referred to herein as even clusters.

Consider the downlink signaling with omni-directional antennas at the subscribers. From Figure 8, it is clear that for the downlink in the shaded sectors, Cell A interferes with Cell B, which in turn interferes with Cell C, which in turn interferes with Cell A, namely, A -> B -> C ->A. For the unshaded sectors, Cell A interferes with Cell

C, which in turn interferes with Cell B, which in turn interferes with Cell A, namely, A -> C -> B ->A.

Sector A1 receives interference from Sector C1, but its transmission interferes with Sector B1. Namely, its interference source and the victims with which it interferes are not the same. This might cause a stability problem in a distributed cluster-allocation system using interference avoidance: if a frequency cluster is assigned in Sector B1 but not in Sector C1, the cluster may be assigned in A1 because it may be seen as clean in A1. However, the assignment of this cluster A1 can cause interference problem to the existing assignment in B1.

In one embodiment, different cluster groups are assigned different priorities for use in different cells to alleviate the aforementioned problem when the traffic load is progressively added to a sector. The priority orders are jointly designed such that a cluster can be selectively assigned to avoid interference from its interference source, while reducing, and potentially minimizing, the probability of causing interference problem to existing assignments in other cells.

Using the aforementioned example, the odd clusters (used by the shaded sectors) are partitioned into 3 groups: Group 1, 2, 3. The priority orders are listed in Table 2.

Table 2: Priority ordering for the downlink of the shaded sectors.

Priority Ordering	Cell A	Cell B	Cell C
1	Group 1	Group 3	Group 2
2	Group 2	Group 1	Group 3
3	Group 3	Group 2	Group 1

Consider Sector A1. First, the clusters in Group 1 are selectively assigned. If there are still more subscribers demanding clusters, the clusters in Group 2 are selectively assigned to subscribers, depending on the measured SINR (avoiding the clusters receiving strong interference from Sector C1). Note that the newly assigned clusters from Group 2 to Sector A1 shall not cause interference problem in Sector B1, unless the load in Sector B1 is so heavy that the clusters in both Group 3 and 1 are used up and the clusters in Group 2 are also used. Table 3 shows the cluster usage when less than 2/3 of all the available clusters are used in Sector A1, B1, and C1.

Table 3: Cluster usage for the downlink of the shaded sectors with less than 2/3 of the full load.

Cluster Usage	Cell A	Cell B	Cell C
1	Group 1	Group 3	Group 2
2	Group 2	Group 1	Group 3
3			

Table 4 shows the priority orders for the unshaded sectors, which are different from those for the shaded sectors, since the interfering relationship is reversed.

Table 4: Priority ordering for the downlink of the unshaded sectors.

Priority Ordering	Cell A	Cell B	Cell C
1	Group 1	Group 2	Group 3
2	Group 2	Group 3	Group 1
3	Group 3	Group 1	Group 2

Intelligent Switching between Coherence and Diversity Clusters

In one embodiment, there are two categories of clusters: coherence clusters, containing multiple subcarriers close to each other and diversity clusters, containing multiple subcarriers with at least some of the subcarriers spread far apart over the spectrum. The closeness of the multiple subcarriers in coherence clusters is preferably within the channel coherence bandwidth, i.e. the bandwidth within which the channel response remains roughly the same, which is typically within 100 kHz for many cellular systems. On the other hand, the spread of subcarriers in diversity clusters is preferably larger than the channel coherence bandwidth, typically within 100 kHz for many cellular systems. Of course, the larger the spread, the better the diversity. Therefore, a general goal in such cases is to maximize the spread.

Figure 9 illustrates exemplary cluster formats for coherence clusters and diversity clusters for Cells A-C. Referring to Figure 9, for cells A-C, the labeling of frequencies (subcarriers) indicates whether the frequencies are part of coherence or diversity clusters. For example, those frequencies labeled 1-8 are diversity clusters and those labeled 9-16 are coherence clusters. For example, all frequencies labeled 1 in a cell are part of one diversity cluster, all frequencies labeled 2 in a cell are part of another diversity cluster, etc., while the group of frequencies labeled 9 are one coherence cluster, the group of

frequencies labeled 10 are another coherence cluster, etc. The diversity clusters can be configured differently for different cells to reduce the effect of inter-cell interference through interference averaging.

Figure 9 shows example cluster configurations for three neighboring cells. The interference from a particular cluster in one cell are distributed to many clusters in other cells, e.g., the interference from Cluster 1 in Cell A are distributed to Cluster 1, 8, 7, 6 in Cell B. This significantly reduces the interference power to any particular cluster in Cell B. Likewise, the interference to any particular cluster in one cell comes from many different clusters in other cells. Since not all cluster are strong interferers, diversity clusters, with channel coding across its subcarriers, provide interference diversity gain. Therefore, it is advantageous to assign diversity clusters to subscribers that are close (e.g., within the coherent bandwidth) to the cell boundaries and are more subject to inter-cell interference.

Since the subcarriers in a coherence cluster are consecutive or close (e.g., within the coherent bandwidth) to each other, they are likely within the coherent bandwidth of the channel fading. Therefore, the channel gain of a coherence cluster can vary significantly and cluster selection can greatly improve the performance. On the other hand, the average channel gain of a diversity cluster has less of a degree of variation due to the inherent frequency diversity among the multiple subcarriers spread over the spectrum. With channel coding across the subcarriers within the cluster, diversity clusters are more robust to cluster mis-selection (by the nature of diversification itself), while yielding possibly less gain from cluster selection. Channel coding across the subcarriers means that each codeword contains bits transmitted from multiple subcarriers, and more specifically, the difference bits between codewords (error vector) are distributed among multiple subcarriers.

More frequency diversity can be obtained through subcarrier hopping over time in which a subscriber occupies a set of subcarriers at one time slot and another different set of subcarriers at a different time slot. One coding unit (frame) contains multiple such time slots and the transmitted bits are encoded across the entire frame.

Figure 10 illustrates diversity cluster with subcarrier hopping. Referring to Figure 10, there are four diversity clusters in each of cells A and B shown, with each subcarrier in individual diversity clusters having the same label (1, 2, 3, or 4). There are four separate time slots shown and during each of the time slots, the subcarriers for each

of the diversity clusters change. For example, in cell A, subcarrier 1 is part of diversity cluster 1 during time slot 1, is part of diversity cluster 2 during time slot 2, is part of diversity cluster 3 during time slot 3, and is part of diversity cluster 4 during time slot 4. Thus, more interference diversity can be obtained through subcarrier hopping over time, with further interference diversity achieved by using different hopping patterns for different cells, as shown in Figure 10.

The manner in which the subscriber changes the subcarriers (hopping sequences) can be different for different cells in order to achieve better interference averaging through coding.

For static subscribers, such as in fixed wireless access, the channels change very little over time. Selective cluster allocation using the coherence clusters achieves good performance. On the other hand, for mobile subscribers, the channel time variance (the variance due to changes in the channel over time) can be very large. A high-gain cluster at one time can be in deep fade at another. Therefore, cluster allocation needs to be updated at a rapid rate, causing significant control overhead. In this case, diversity clusters can be used to provide extra robustness and to alleviate the overhead of frequent cluster reallocation. In one embodiment, cluster allocation is performed faster than the channel changing rate, which is often measured by the channel Doppler rate (in Hz), i.e. how many cycles the channel changes per second where the channel is completely different after one cycle. Note that selective cluster allocation can be performed on both coherence and diversity clusters.

In one embodiment, for cells containing mixed mobile and fixed subscribers, a channel/interference variation detector can be implemented at either the subscriber or the base station, or both. Using the detection results, the subscriber and the base station intelligently selects diversity clusters to mobile subscribers or fixed subscribers at cell boundaries, and coherence clusters to fixed subscribers close to the base station. The channel/interference variation detector measures the channel (SINR) variation from time to time for each cluster. For example, in one embodiment, the channel/interference detector measures the power difference between pilot symbols for each cluster and averages the difference over a moving window (e.g., 4 time slots). A large difference indicates that channel/interference changes frequently and subcarrier allocation may be not reliable. In such a case, diversity clusters are more desirable for the subscriber.

Figure 11 is a flow diagram of one embodiment of a process for intelligent selection between diversity clusters and coherence clusters depending on subscribers mobility. The process is performed by processing logic that may comprise hardware (e.g., circuitry, dedicated logic, etc.), software (such as that which runs on, for example, a general purpose computer system or dedicated machine), or a combination of both.

Referring to Figure 11, processing logic in the base station performs channel/interference variation detection (processing block 1101). Processing logic then tests whether the results of the channel/interference variation detection indicate that the user is mobile or in a fixed position close to the edge of the cell (processing block 1102). If the user is not mobile or is not in a fixed position close to the edge of the cell, processing transitions to processing block 1103 where processing logic in the base station selects coherence clusters; otherwise, processing transitions to processing block 1104 in which processing logic in the base station selects diversity clusters.

The selection can be updated and intelligently switched during retraining.

The ratio/allocation of the numbers of coherence and diversity clusters in a cell depends on the ratio of the population of mobile and fixed subscribers. When the population changes as the system evolves, the allocation of coherence and diversity clusters can be reconfigured to accommodate the new system needs. Figure 12 illustrates a reconfiguration of cluster classification which can support more mobile subscribers than that in Figure 9.

Whereas many alterations and modifications of the present invention will no doubt become apparent to a person of ordinary skill in the art after having read the foregoing description, it is to be understood that any particular embodiment shown and described by way of illustration is in no way intended to be considered limiting. Therefore, references to details of various embodiments are not intended to limit the scope of the claims which in themselves recite only those features regarded as essential to the invention.

CLAIMS

We claim:

1. A method for subcarrier selection for a system employing orthogonal frequency division multiple access (OFDMA) comprising:

a subscriber measuring channel and interference information for a plurality of subcarriers based on pilot symbols received from a base station;

the subscriber selecting a set of candidate subcarriers;

the subscriber providing feedback information on the set of candidate subcarriers to the base station; and

the subscriber receiving an indication of subcarriers of the set of subcarriers selected by the base station for use by the subscriber.

2. The method defined in Claim 1 further comprising the subscriber continuously monitoring reception of the pilot symbols known to the base station and measuring signal-plus-interference-to-noise ratio (SINR) of each cluster of subcarriers.

3. The method defined in Claim 2 further comprising the subscriber measuring inter-cell interference, wherein the subscriber selects candidate subcarriers based on the inter-cell interference.

4. The method defined in Claim 3 further comprising the base station selecting subcarriers for the subscriber based on inter-cell interference avoidance.

5. The method defined in Claim 2 further comprising the subscriber measuring intra-cell traffic, wherein the subscriber selects candidate subcarriers based on the intra-cell traffic load balancing.

6. The method defined in Claim 5 further comprising the base station selecting the subcarriers in order to balance intra-cell traffic load on each cluster.

7. The method defined in Claim 1 further comprising the subscriber submitting new feedback information after being allocated the set of subscribers to be allocated a new set of subcarriers and thereafter the subscriber receiving another indication of the new set of subcarriers.

8. The method defined in Claim 1 further comprising the subscriber using information from pilot symbol periods and data periods to measure channel and interference information.

9. The method defined in Claim 8 wherein the subscriber selects candidate subcarriers based on the SINR of a cluster of subcarriers and a difference between measured power corresponding to each cluster during pilot periods and measured power during data periods.

10. The method defined in Claim 9 further comprising the subscriber using the power difference to distinguish, during selection, clusters of subcarriers having substantially similar SINRs.

11. The method defined in Claim 8 further comprising the subscriber using information from pilot symbol periods and data traffic periods to analyze presence of intra-cell traffic load and inter-cell interference.

12. The method defined in Claim 1 wherein the pilot symbols occupy an entire OFDM frequency bandwidth.

13. The method defined in Claim 12 wherein at least one other pilot symbol from a different cell transmitted at the same time as the pilot symbols received from the base station collide with each other.

14. The method defined in Claim 1 further comprising the base station selecting the subcarriers from the set of candidate subcarriers based on additional information available to the base station.

15. The method defined in Claim 14 wherein the additional information comprises traffic load information on each cluster of subcarriers.

16. The method defined in Claim 15 wherein the traffic load information is provided by a data buffer in the base station.

17. The method defined in Claim 1 wherein the indication of subcarriers is received via a downlink control channel.

18. The method defined in Claim 1 wherein the plurality of subcarriers comprises all subcarriers allocable by a base station.

19. The method defined in Claim 1 wherein providing feedback information comprises arbitrarily ordering the set of candidate of subcarriers as clusters of subcarriers.

20. The method defined in Claim 19 wherein arbitrarily order candidate clusters comprise clusters in an order with most desirable candidate clusters being listed first.

21. The method defined in Claim 19 wherein the feedback information includes an index indication of a candidate cluster with its SINR value.

22. The method defined in Claim 21 wherein each index is indicative of a coding and modulation rate.

23. The method defined in Claim 1 wherein providing feedback information comprises sequentially ordering candidate clusters.

24. The method defined in Claim 1 further comprising the subscriber sending an indication of coding and modulation rates that the subscriber desires to employ for each cluster.

25. The method defined in Claim 24 wherein the indication of coding and modulation rates comprises an SINR index indicative of a coding and modulation rate.

26. The method defined in Claim 1 further comprising:

the base station allocating a first portion of the subcarriers to establish a data link between the base station and the subscriber; and then

the base station allocating a second portion of the subcarriers to the subscriber to increase communication bandwidth.

27. The method defined in Claim 26 wherein the base station allocates the second portion after allocating each subscriber in the cell subcarriers to establish a data link between the base station and said each subscriber.

28. The method defined in Claim 26 wherein, due to subscriber priority, the base station allocates the second portion before allocating each subscriber in the cell subcarriers to establish their data link to the base station.

29. An apparatus comprising:

a plurality of subscribers in a first cell to generate feedback information indicating clusters of subcarriers desired for use by the plurality of subscribers; and

a first base station in the first cell, the first base station performing subcarrier allocation for OFDMA to allocate OFDMA subcarriers in clusters to the plurality of subscribers based on inter-cell interference avoidance and intra-cell traffic load balancing in response to the feedback information.

30. An apparatus comprising:

a plurality of subscribers in a first cell to generate feedback information indicating clusters of subcarriers desired for use by the plurality of subscribers; and

a first base station in the first cell, the first base station to allocate OFDMA subcarriers in clusters to the plurality of subscribers;

each of a plurality of subscribers to measure channel and interference information for the plurality of subcarriers based on pilot symbols received from the first base station and at least one of the plurality of subscribers to select a set of candidate subcarriers from the plurality of subcarriers, and the one subscriber to provide feedback information on the set of candidate subcarriers to the base station and to receive an indication of subcarriers from the set of subcarriers selected by the first base station for use by the one subscriber.

31. The apparatus defined in Claim 30 wherein each of the plurality of subscribers continuously monitors reception of the pilot symbols known to the base station and the plurality of subscribers and measures signal-plus-interference-to-noise ratio (SINR) of each cluster of subcarriers.

32. The apparatus defined in Claim 31 wherein each of the plurality of subscribers measures inter-cell interference, wherein the at least one subscriber selects candidate subcarriers based on the inter-cell interference.

33. The apparatus defined in Claim 32 wherein the base station selects subcarriers for the one subscriber based on inter-cell interference avoidance.

34. The apparatus defined in Claim 31 wherein each of the plurality of subscribers measures intra-cell traffic, wherein the at least one subscriber selects candidate subcarriers based on the intra-cell traffic load balancing.

35. The apparatus defined in Claim 34 wherein the base station selects subcarriers in order to balance intra-cell traffic load on each cluster of subcarriers.

36. The apparatus defined in Claim 30 wherein the subscriber submits new feedback information after being allocated the set of subscribers to receive a new set of subcarriers and thereafter receives another indication of the new set of subcarriers.

37. The apparatus defined in Claim 30 wherein the at least one subscriber uses information from pilot symbol periods and data periods to measure channel and interference information.

38. The apparatus defined in Claim 30 wherein the at least one subscriber selects candidate subcarriers based on SINR of the cluster and a difference between

measured power corresponding to each cluster during pilot periods and measured power during data periods.

39. The apparatus defined in Claim 38 wherein the one subscriber distinguishes, during selection, cluster of subcarriers having substantially similar SINRs based on the power difference.

40. The apparatus defined in Claim 38 wherein the at least one subscriber uses information from pilot symbol periods and data traffic periods to analyze presence of intra-cell traffic load and inter-cell interference.

41. The apparatus defined in Claim 38 wherein the pilot symbols occupy an entire OFDM frequency bandwidth.

42. The apparatus defined in Claim 41 wherein at least one other pilot symbol from a different cell transmitted at the same time as the pilot symbols received from the base station collide with each other.

43. The apparatus defined in Claim 30 wherein the base station selects the subcarriers from the set of candidate subcarriers based on additional information available to the base station.

44. The apparatus defined in Claim 43 wherein the additional information comprises traffic load information on each cluster of subcarriers.

45. The apparatus defined in Claim 44 wherein the traffic load information is provided by a data buffer in the base station.

46. The apparatus defined in Claim 30 wherein the indication of subcarriers is received via a downlink control channel between the base station and the at least one subscriber.

47. The apparatus defined in Claim 30 wherein the plurality of subcarriers comprises all subcarriers allocable by a base station.

48. The apparatus defined in Claim 30 wherein the plurality of subscribers provide feedback information that comprises an arbitrarily ordered set of candidate subcarriers as clusters of subcarriers.

49. The apparatus defined in Claim 48 wherein arbitrarily order candidate clusters comprise clusters in an order with most desirable candidate clusters being listed first.

50. The apparatus defined in Claim 48 wherein the feedback information includes an index indication of a candidate cluster with it SINR value.

51. The apparatus defined in Claim 50 wherein each index is indicative of a coding and modulation rate.

52. The apparatus defined in Claim 30 wherein providing feedback information comprises sequentially ordering candidate clusters.

53. The apparatus defined in Claim 30 wherein the one subscriber sends an indication of coding and modulation rates that the one subscriber desires to employ.

54. The apparatus defined in Claim 53 wherein the indication of coding and modulation rates comprises an SINR index indicative of a coding and modulation rate.

55. The apparatus defined in Claim 30 wherein the base station allocates a first portion of the subcarriers to establish a data link between the base station and the subscriber; and then allocates a second portion of the subcarriers to the subscriber to increase communication bandwidth.

56. The apparatus defined in Claim 55 wherein the base station allocates the second portion after allocating each subscriber in the cell subcarriers to establish a data link between the base station and said each subscriber.

57. The apparatus defined in Claim 55 wherein, due to subscriber priority, the base station allocates the second portion before allocating each subscriber in the cell subcarriers to establish their data link to the base station.

58. A method comprising:

the base station allocating a first portion of the subcarriers to establish a data link between the base station and the subscriber; and then

the base station allocating a second portion of the subcarriers to the subscriber to increase communication bandwidth.

59. The method defined in Claim 57 wherein the base station allocates the second portion after allocating each subscriber in the cell subcarriers to establish a data link between the base station and said each subscriber.

60. A base station comprising:

means for allocating a first portion of the subcarriers to establish a data link between the base station and the subscriber; and

means for allocating a second portion of the subcarriers to the subscriber to increase communication bandwidth.

61. The apparatus defined in Claim 60 wherein the base station allocates the second portion after allocating each subscriber in the cell subcarriers to establish a data link between the base station and said each subscriber.

62. An apparatus comprising:

a plurality of subscribers in a cell; and

a base station in the cell, the base station to perform subcarrier allocation for OFDMA to allocate OFDMA subcarriers in clusters to the plurality of subscribers based on inter-cell interference avoidance and intra-cell traffic load balancing.

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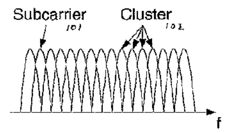

Figure 1A

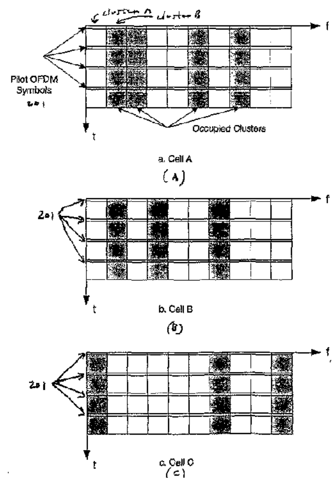

Figure 2

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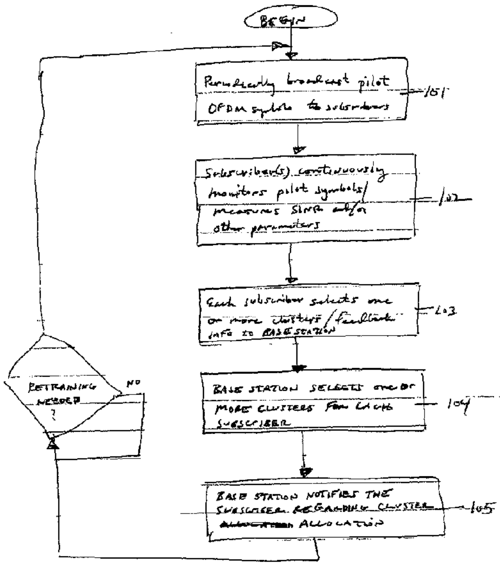
BEGIN
Periodically broadcast pilot OFDM symbols to subscribers
101
Subscriber(s) continuously monitors pilot symbols/ measures SINR and/or other parameters
102
Each subscriber selects one or more clusters/feedback info to BASE STATION
103
BASE STATION SELECTS one or MORE CLUSTERS FOR EACH SUBSCRIBER
104
BASE STATION NOTIFIES THE SUBSCRIBER REGARDING CLUSTER ALLOCATION
105
RETRAINING NEEDED ?
NO

Figure 1B

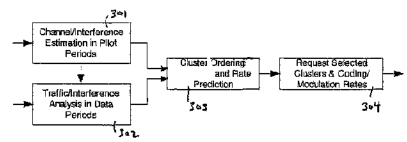

Figure 3.

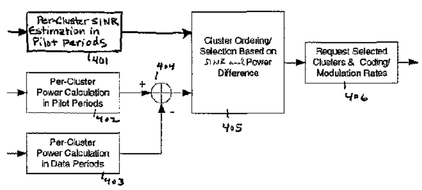

Figure 4

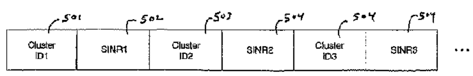

Figure 5

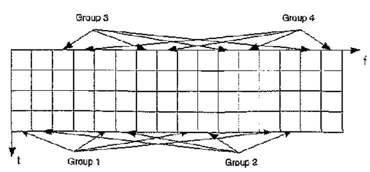

Figure 6

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Group ID1	SINR1	SINR2	SINR3	Group ID2	SINR1	SINR2	SINR3

Figure 7

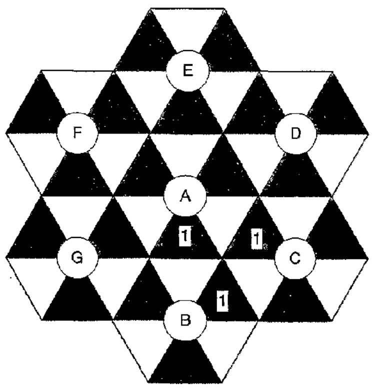

Figure 8

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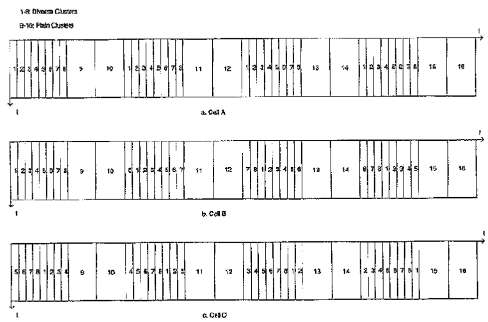

Figure 9

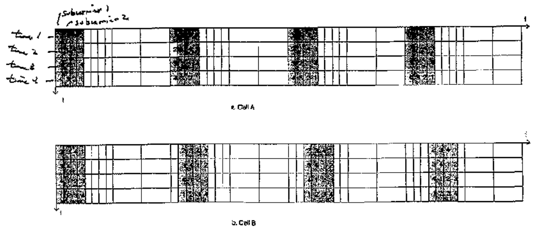

Figure 10

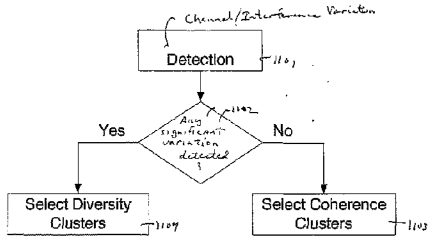

Figure 11

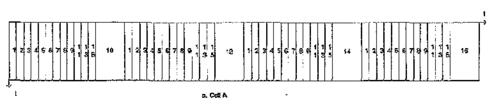

Figure 12

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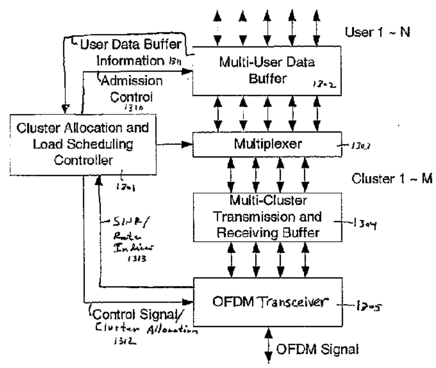
User 1 ~ N
User Data Buffer Information
Admission Control
Multi-User Data Buffer
Cluster Allocation and Load Scheduling Controller
Multiplexer
Cluster 1 ~ M
Multi-Cluster Transmission and Receiving Buffer
OFDM Transceiver
Control Signal/ Cluster Allocation
OFDM Signal

Figure 13

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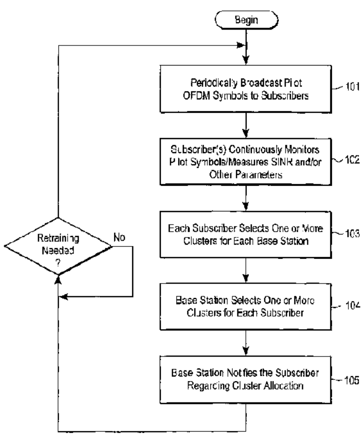
[Continued on next page]

(54) Title: OFDMA WITH ADAPTIVE SUBCARRIER-CLUSTER CONFIGURATION AND SELECTIVE LOADING



(57) Abstract: A method and apparatus for subcarrier selection for systems is described. In one embodiment, the system employs orthogonal frequency division multiple access (OFDMA). In one embodiment, a method for subcarrier selection compreses each of multiple subscribes measuring channel and interference information for subcarriers based on pilot symbols received from a base station, at least one of subscribers selecting a set of candidate subcarriers, providing feedback information on the set of candidate subcarriers to the base station, andthe one subscriber receiving an indicaiton of subcarriers to the base station, and the one subscriber receiving an indication of subcarriers of the set of subcarriers selected bz the base station for use by the one subscriber.

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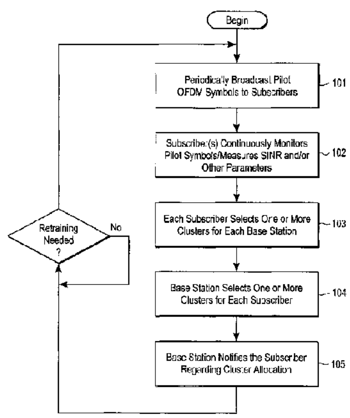

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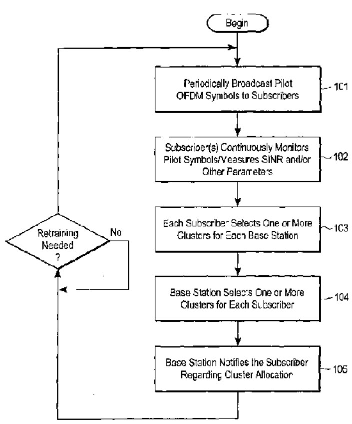

(57) Abstract: A method and apparatus for subcarrier selection for systems is described. In one embodiment, the system employs orthogonal frequency division multiple access (OFDMA). In one embodiment, a method for subcarrier selection compreses each of multiple subscribes measuring channel and interference information for subcarriers based on pilot symbols received from a base station, at least one of subscribers selecting a set of candidate subcarriers, providing feedback information on the set of candidate subcarriers to the base station, andthe one subscriber receiving an indicaiton of subcarriers to the base station, and the one subscriber receiving an indication of subcarriers of the set of subcarriers selected bz the base station for use by the one subscriber.

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OFDMA WITH ADAPTIVE SUBCARRIER-CLUSTER CONFIGURATION AND SELECTIVE LOADING

FIELD OF THE INVENTION

The invention relates to the field of wireless communications; more particularly, the invention relates to multi-cell, multi-subscriber wireless systems using orthogonal frequency division multiplexing (OFDM).

BACKGROUND OF THE INVENTION

Orthogonal frequency division multiplexing (OFDM) is an efficient modulation scheme for signal transmission over frequency-selective channels. In OFDM, a wide bandwidth is divided into multiple narrow-band subcarriers, which are arranged to be orthogonal with each other. The signals modulated on the subcarriers are transmitted in parallel. For more information, see Cimini, Jr., "Analysis and Simulation of a Digital Mobile Channel Using Orthogonal Frequency Division Multiplexing," IEEE Trans. Commun., vol. COM-33, no. 7, July 1985, pp. 665-75; Chuang and Sollenberger, "Beyond 3G: Wideband Wireless Data Access Based on OFDM and Dynamic Packet Assignment," IEEE Communications Magazine, Vol. 38, No. 7, pp. 78–87, July 2000.

One way to use OFDM to support multiple access for multiple subscribers is through time division multiple access (TDMA), in which each subscriber uses all the subcarriers within its assigned time slots. Orthogonal frequency division multiple access (OFDMA) is another method for multiple access, using the basic format of OFDM. In OFDMA, multiple subscribers simultaneously use different subcarriers, in a fashion similar to frequency division multiple access (FDMA). For more information, see Sari and Karam, "Orthogonal Frequency-Division Multiple Access and its Application to CATV Networks," European Transactions on Telecommunications, Vol. 9 (6), pp. 507-516, Nov./Dec. 1998 and Nogueroles, Bossert, Donder, and Zyablov, "Improved Performance of a Random OFDMA Mobile Communication System,", Proceedings of IEEE VTC'98, pp. 2502 –2506.

Multipath causes frequency-selective fading. The channel gains are different for different subcarriers. Furthermore, the channels are typically uncorrelated for different subscribers. The subcarriers that are in deep fade for one subscriber may provide high channel gains for another subscriber. Therefore, it is advantageous in an OFDMA

system to adaptively allocate the subcarriers to subscribers so that each subscriber enjoys a high channel gain. For more information, see Wong et al., "Multiuser OFDM with Adaptive Subcarrier, Bit and Power Allocation," IEEE J. Select. Areas Commun., Vol. 17(10), pp. 1747-1758, October 1999.

Within one cell, the subscribers can be coordinated to have different subcarriers in OFDMA. The signals for different subscribers can be made orthogonal and there is little intracell interference. However, with aggressive frequency reuse plan, e.g., the same spectrum is used for multiple neighboring cells, the problem of intercell interference arises. It is clear that the intercell interference in an OFDMA system is also frequency selective and it is advantageous to adaptively allocate the subcarriers so as to mitigate the effect of intercell interference.

One approach to subcarrier allocation for OFDMA is a joint optimization operation, not only requiring the activity and channel knowledge of all the subscribers in all the cells, but also requiring frequent rescheduling every time an existing subscribers is dropped off the network or a new subscribers is added onto the network. This is often impractical in real wireless system, mainly due to the bandwidth cost for updating the subscriber information and the computation cost for the joint optimization.

SUMMARY OF THE INVENTION

A method and apparatus for subcarrier selection for systems is described. In one embodiment, the system employs orthogonal frequency division multiple access (OFDMA). In one embodiment, a method for subcarrier selection comprises a subscriber measuring channel and interference information for subcarriers based on pilot symbols received from a base station, the subscriber selecting a set of candidate subcarriers, providing feedback information on the set of candidate subcarriers to the base station, and receiving an indication of subcarriers of the set of subcarriers selected by the base station for use by the subscriber.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be understood more fully from the detailed description given below and from the accompanying drawings of various embodiments of the invention, which, however, should not be taken to limit the invention to the specific embodiments, but are for explanation and understanding only.

Figure 1A illustrates subcarriers and clusters.

Figure 1B is a flow diagram of one embodiment of a process for allocating subcarriers.

Figure 2 illustrates time and frequency grid of OFDM symbols, pilots and clusters.

Figure 3 illustrates subscriber processing.

Figure 4 illustrates one example of Figure 3.

Figure 5 illustrates one embodiment of a format for arbitrary cluster feedback.

Figure 6 illustrates one embodiment of a partition the clusters into groups.

Figure 7 illustrates one embodiment of a feedback format for group-based cluster allocation.

Figure 8 illustrates frequency reuse and interference in a multi-cell, multi-sector network.

Figure 9 illustrates different cluster formats for coherence clusters and diversity clusters.

Figure 10 illustrates diversity clusters with subcarrier hopping.

Figure 11 illustrates intelligent switching between diversity clusters and coherence clusters depending on subscribers mobility.

Figure 12 illustrates one embodiment of a reconfiguration of cluster classification.

Figure 13 illustrates one embodiment of a base station.

DETAILED DESCRIPTION OF THE PRESENT INVENTION

A distributed, reduced-complexity approach for subcarrier allocation is described. The techniques disclosed herein are described using OFDMA (clusters) as an example. However, they are not limited to OFDMA-based systems. The techniques apply to multi-carrier systems in general, where, for example, a carrier can be a cluster in OFDMA, a spreading code in CDMA, an antenna beam in SDMA (space-division multiple access), etc. In one embodiment, subcarrier allocation is performed in each cell separately. Within each cell, the allocation for individual subscribers (e.g., mobiles) is also made progressively as each new subscriber is added to the system as opposed to joint allocation for subscribers within each cell in which allocation decisions are made taking into account all subscribers in a cell for each allocation.

For downlink channels, each subscriber first measures the channel and interference information for all the subcarriers and then selects multiple subcarriers with good performance (e.g., a high signal-to-interference plus noise ratio (SINR)) and feeds back the information on these candidate subcarriers to the base station. The feedback may comprise channel and interference information (e.g., signal-to-interference-plus-noise-ratio information) on all subcarriers or just a portion of subcarriers. In case of providing information on only a portion of the subcarriers, a subscriber may provide a list of subcarriers ordered starting with those subcarriers which the subscriber desires to use, usually because their performance is good or better than that of other subcarriers.

Upon receiving the information from the subscriber, the base station further selects the subcarriers among the candidates, utilizing additional information available at the base station, e.g., the traffic load information on each subcarrier, amount of traffic requests queued at the base station for each frequency band, whether frequency bands are overused, and/or how long a subscriber has been waiting to send information. In one embodiment, the subcarrier loading information of neighboring cells can also be exchanged between base stations. The base stations can use this information in subcarrier allocation to reduce inter-cell interference.

In one embodiment, the selection by the base station of the channels to allocate, based on the feedback, results in the selection of coding/modulation rates. Such coding/modulation rates may be specified by the subscriber when specifying subcarriers that it finds favorable to use. For example, if the SINR is less than a certain threshold (e.g., 12 dB), quadrature phase shift keying (QPSK) modulation is used; otherwise, 16 quadrature amplitude modulation (QAM) is used. Then the base station informs the subscribers about the subcarrier allocation and the coding/modulation rates to use.

In one embodiment, the feedback information for downlink subcarrier allocation is transmitted to the base station through the uplink access channel, which occurs in a short period every transmission time slot, e.g., 400 microseconds in every 10-millisecond time slot. In one embodiment, the access channel occupies the entire frequency bandwidth. Then the base station can collect the uplink SINR of each subcarrier directly from the access channel. The SINR as well as the traffic load information on the uplink subcarriers are used for uplink subcarrier allocation.

For either direction, the base station makes the final decision of subcarrier allocation for each subscriber.

In the following description, a procedure of selective subcarrier allocation is also disclosed, including methods of channel and interference sensing, methods of information feedback from the subscribers to the base station, and algorithms used by the base station for subcarrier selections.

In the following description, numerous details are set forth to provide a thorough understanding of the present invention. It will be apparent, however, to one skilled in the art, that the present invention may be practiced without these specific details. In other instances, well-known structures and devices are shown in block diagram form, rather than in detail, in order to avoid obscuring the present invention.

Some portions of the detailed descriptions which follow are presented in terms of algorithms and symbolic representations of operations on data bits within a computer memory. These algorithmic descriptions and representations are the means used by those skilled in the data processing arts to most effectively convey the substance of their work to others skilled in the art. An algorithm is here, and generally, conceived to be a self-consistent sequence of steps leading to a desired result. The steps are those requiring physical manipulations of physical quantities. Usually, though not necessarily, these quantities take the form of electrical or magnetic signals capable of being stored, transferred, combined, compared, and otherwise manipulated. It has proven convenient at times, principally for reasons of common usage, to refer to these signals as bits, values, elements, symbols, characters, terms, numbers, or the like.

It should be borne in mind, however, that all of these and similar terms are to be associated with the appropriate physical quantities and are merely convenient labels applied to these quantities. Unless specifically stated otherwise as apparent from the following discussion, it is appreciated that throughout the description, discussions utilizing terms such as "processing" or "computing" or "calculating" or "determining" or "displaying" or the like, refer to the action and processes of a computer system, or similar electronic computing device, that manipulates and transforms data represented as physical (electronic) quantities within the computer system's registers and memories into other data similarly represented as physical quantities within the computer system memories or registers or other such information storage, transmission or display devices.

The present invention also relates to apparatus for performing the operations herein. This apparatus may be specially constructed for the required purposes, or it may comprise a general purpose computer selectively activated or reconfigured by a computer

program stored in the computer. Such a computer program may be stored in a computer readable storage medium, such as, but is not limited to, any type of disk including floppy disks, optical disks, CD-ROMs, and magnetic-optical disks, read-only memories (ROMs), random access memories (RAMs), EPROMs, EEPROMs, magnetic or optical cards, or any type of media suitable for storing electronic instructions, and each coupled to a computer system bus.

The algorithms and displays presented herein are not inherently related to any particular computer or other apparatus. Various general purpose systems may be used with programs in accordance with the teachings herein, or it may prove convenient to construct more specialized apparatus to perform the required method steps. The required structure for a variety of these systems will appear from the description below. In addition, the present invention is not described with reference to any particular programming language. It will be appreciated that a variety of programming languages may be used to implement the teachings of the invention as described herein.

A machine-readable medium includes any mechanism for storing or transmitting information in a form readable by a machine (e.g., a computer). For example, a machine-readable medium includes read only memory ("ROM"); random access memory ("RAM"); magnetic disk storage media; optical storage media; flash memory devices; electrical, optical, acoustical or other form of propagated signals (e.g., carrier waves, infrared signals, digital signals, etc.); etc.

Subcarrier Clustering

The techniques described herein are directed to subcarrier allocation for data traffic channels. In a cellular system, there are typically other channels, pre-allocated for the exchange of control information and other purposes. These channels often include down link and up link control channels, uplink access channels, and time and frequency synchronization channels.

Figure 1A illustrates multiple subcarriers, such as subcarrier 101, and cluster 102. A cluster, such as cluster 102, is defined as a logical unit that contains at least one physical subcarrier, as shown in Figure 1A. A cluster can contain consecutive or disjoint subcarriers. The mapping between a cluster and its subcarriers can be fixed or reconfigurable. In the latter case, the base station informs the subscribers when the clusters are redefined. In one embodiment, the frequency spectrum includes 512

subcarriers and each cluster includes four consecutive subcarriers, thereby resulting in 128 clusters.

An Exemplary Subcarrier/Cluster Allocation Procedure

Figure 1B is a flow diagram of one embodiment of a process for allocation clusters to subscribers. The process is performed by processing logic that may comprise hardware (e.g., dedicated logic, circuitry, etc.), software (such as that which runs on, for example, a general purpose computer system or dedicated machine), or a combination of both.

Referring to Figure 1B, each base station periodically broadcasts pilot OFDM symbols to every subscriber within its cell (or sector) (processing block 101). The pilot symbols, often referred to as a sounding sequence or signal, are known to both the base station and the subscribers. In one embodiment, each pilot symbol covers the entire OFDM frequency bandwidth. The pilot symbols may be different for different cells (or sectors). The pilot symbols can serve multiple purposes: time and frequency synchronization, channel estimation and signal-to-interference/noise (SINR) ratio measurement for cluster allocation.

Next, each subscriber continuously monitors the reception of the pilot symbols and measures the SINR and/or other parameters, including inter-cell interference and intra-cell traffic, of each cluster (processing block 102). Based on this information, each subscriber selects one or more clusters with good performance (e.g., high SINR and low traffic loading) relative to each other and feeds back the information on these candidate clusters to the base station through predefined uplink access channels (processing block 103). For example, SINR values higher than 10 dB may indicate good performance. Likewise, a cluster utilization factor less than 50% may be indicative of good performance. Each subscriber selects the clusters with relatively better performance than others. The selection results in each subscriber selecting clusters they would prefer to use based on the measured parameters.

In one embodiment, each subscriber measures the SINR of each subcarrier cluster and reports these SINR measurements to their base station through an access channel. The SINR value may comprise the average of the SINR values of each of the subcarriers in the cluster. Alternatively, the SINR value for the cluster may be the worst SINR among the SINR values of the subcarriers in the cluster. In still another embodiment, a

weighted averaging of SINR values of the subcarriers in the cluster is used to generate an SINR value for the cluster. This may be particularly useful in diversity clusters where the weighting applied to the subcarriers may be different.

The feedback of information from each subscriber to the base station contains a SINR value for each cluster and also indicates the coding/modulation rate that the subscriber desires to use. No cluster index is needed to indicate which SINR value in the feedback corresponds to which cluster as long as the order of information in the feedback is known to the base station. In an alternative embodiment, the information in the feedback is ordered according to which clusters have the best performance relative to each other for the subscriber. In such a case, an index is needed to indicate to which cluster the accompanying SINR value corresponds.

Upon receiving the feedback from a subscriber, the base station further selects one or more clusters for the subscriber among the candidates (processing block 104). The base station may utilize additional information available at the base station, e.g., the traffic load information on each subcarrier, amount of traffic requests queued at the base station for each frequency band, whether frequency bands are overused, and how long a subscriber has been waiting to send information. The subcarrier loading information of neighboring cells can also be exchanged between base stations. The base stations can use this information in subcarrier allocation to reduce inter-cell interference.

After cluster selection, the base station notifies the subscriber about the cluster allocation through a downlink common control channel or through a dedicated downlink traffic channel if the connection to the subscriber has already been established (processing block 105). In one embodiment, the base station also informs the subscriber about the appropriate modulation/coding rates.

Once the basic communication link is established, each subscriber can continue to send the feedback to the base station using a dedicated traffic channel (e.g., one or more predefined uplink access channels).

In one embodiment, the base station allocates all the clusters to be used by a subscriber at once. In an alternative embodiment, the base station first allocates multiple clusters, referred to herein as the basic clusters, to establish a data link between the base station and the subscriber. The base station then subsequently allocates more clusters, referred to herein as the auxiliary clusters, to the subscriber to increase the communication bandwidth. Higher priorities can be given to the assignment of basic

clusters and lower priorities may be given to that of auxiliary clusters. For example, the base station first ensures the assignment of the basic clusters to the subscribers and then tries to satisfy further requests on the auxiliary clusters from the subscribers. Alternatively, the base station may assign auxiliary clusters to one or more subscribers before allocating basic clusters to other subscribers. For example, a base station may allocate basic and auxiliary clusters to one subscriber before allocating any clusters to other subscribers. In one embodiment, the base station allocates basic clusters to a new subscriber and then determines if there are any other subscribers requesting clusters. If not, then the base station allocates the auxiliary clusters to that new subscriber.

From time to time, processing logic performs retraining by repeating the process described above (processing block 106). The retraining may be performed periodically. This retraining compensates for subscriber movement and any changes in interference. In one embodiment, each subscriber reports to the base station its updated selection of clusters and their associated SINRs. Then the base station further performs the reselection and informs the subscriber about the new cluster allocation. Retraining can be initiated by the base station, and in which case, the base station requests a specific subscriber to report its updated cluster selection. Retraining can also be initiated by the subscriber when it observes channel deterioration.

Adaptive Modulation and Coding

In one embodiment, different modulation and coding rates are used to support reliable transmission over channels with different SINR. Signal spreading over multiple subcarriers may also be used to improve the reliability at very low SINR.

An example coding/modulation table is given below in Table 1.

Table 1

Scheme	Modulation	Code Rate
0	QPSK, 1/8 Spreading	½
1	QPSK, ¼ Spreading	½
2	QPSK, ½ Spreading	½
3	QPSK	½
4	8PSK	2/3
5	16QAM	3/4
6	64QAM	5/6

In the example above, 1/8 spreading indicates that one QPSK modulation symbol is repeated over eight subcarriers. The repetition/spreading may also be extended to the time domain. For example, one QPSK symbol can be repeated over four subcarriers of two OFDM symbols, resulting also 1/8 spreading.

The coding/modulation rate can be adaptively changed according to the channel conditions observed at the receiver after the initial cluster allocation and rate selection.

Pilot Symbols and SINR Measurement

In one embodiment, each base station transmits pilot symbols simultaneously, and each pilot symbol occupies the entire OFDM frequency bandwidth, as shown in Figures 2A-C. Referring to Figure 2A-C, pilot symbols 201 are shown traversing the entire OFDM frequency bandwidth for cells A, B and C, respectively. In one embodiment, each of the pilot symbols have a length or duration of 128 microseconds with a guard time, the combination of which is approximately 152 microseconds. After each pilot period, there are a predetermined number of data periods followed by another set of pilot symbols. In one embodiment, there are four data periods used to transmit data after each pilot, and each of the data periods is 152 microseconds.

A subscriber estimates the SINR for each cluster from the pilot symbols. In one embodiment, the subscriber first estimates the channel response, including the amplitude and phase, as if there is no interference or noise. Once the channel is estimated, the subscriber calculates the interference/noise from the received signal.

The estimated SINR values may be ordered from largest to smallest SINRs and the clusters with large SINR values are selected. In one embodiment, the selected

clusters have SINR values that are larger than the minimum SINR which still allows a reliable (albeit low-rate) transmission supported by the system. The number of clusters selected may depend on the feedback bandwidth and the request transmission rate. In one embodiment, the subscriber always tries to send the information about as many clusters as possible from which the base station chooses.

The estimated SINR values are also used to choose the appropriate coding/modulation rate for each cluster as discussed above. By using an appropriate SINR indexing scheme, an SINR index may also indicate a particular coding and modulation rate that a subscriber desires to use. Note that even for the same subscribers, different clusters can have different modulation/coding rates.

Pilot symbols serve an additional purpose in determining interference among the cells. Since the pilots of multiple cells are broadcast at the same time, they will interfere with each other (because they occupy the entire frequency band). This collision of pilot symbols may be used to determine the amount of interference as a worst case scenario. Therefore, in one embodiment, the above SINR estimation using this method is conservative in that the measured interference level is the worst-case scenario, assuming that all the interference sources are on. Thus, the structure of pilot symbols is such that it occupies the entire frequency band and causes collisions among different cells for use in detecting the worst case SINR in packet transmission systems.

During data traffic periods, the subscribers can determine the level of interference again. The data traffic periods are used to estimate the intra-cell traffic as well as the inter-cell interference level. Specifically, the power difference during the pilot and traffic periods may be used to sense the (intra-cell) traffic loading and inter-cell interference to select the desirable clusters.

The interference level on certain clusters may be lower, because these clusters may be unused in the neighboring cells. For example, in cell A, with respect to cluster A there is less interference because cluster A is unused in cell B (while it is used in cell C). Similarly, in cell A, cluster B will experience lower interference from cell B because cluster B is used in cell B but not in cell C.

The modulation/coding rate based on this estimation is robust to frequent interference changes resulted from bursty packet transmission. This is because the rate prediction is based on the worst case situation in which all interference sources are transmitting.

In one embodiment, a subscriber utilizes the information available from both the pilot symbol periods and the data traffic periods to analyze the presence of both the intra-cell traffic load and inter-cell interference. The goal of the subscriber is to provide an indication to the base station as to those clusters that the subscriber desires to use. Ideally, the result of the selection by the subscriber is clusters with high channel gain, low interference from other cells, and high availability. The subscriber provides feedback information that includes the results, listing desired clusters in order or not as described herein.

Figure 3 illustrates one embodiment of subscriber processing. The processing is performed by processing logic that may comprise hardware (e.g., dedicated logic, circuitry, etc.), software (such as that which runs on, for example, a general purpose computer system or dedicated machine), or a combination of both.

Referring to Figure 3, channel/interference estimation processing block 301 performs channel and interference estimation in pilot periods in response to pilot symbols. Traffic/interference analysis processing block 302 performs traffic and interference analysis in data periods in response to signal information and information from channel/interference estimation block 301.

Cluster ordering and rate prediction processing block 303 is coupled to outputs of channel/interference estimation processing block 301 and traffic/interference analysis processing block 302 to perform cluster ordering and selection along with rate prediction.

The output of cluster ordering processing block 303 is input to cluster request processing block 304, which requests clusters and modulation/coding rates. Indications of these selections are sent to the base station. In one embodiment, the SINR on each cluster is reported to the base station through an access channel. The information is used for cluster selection to avoid clusters with heavy intra-cell traffic loading and/or strong interference from other cells. That is, a new subscriber may not be allocated use of a particular cluster if heavy intra-cell traffic loading already exists with respect to that cluster. Also, clusters may not be allocated if the interference is so strong that the SINR only allows for low-rate transmission or no reliable transmission at all.

The channel/interference estimation by processing block 301 is well-known in the art by monitoring the interference that is generated due to full-bandwidth pilot symbols being simultaneously broadcast in multiple cells. The interface information is

forwarded to processing block 302 which uses the information to solve the following equation:

$$H_i S_i + I_i + n_i = y_i$$

where S_i represents the signal for subcarrier (freq. band) i, I_i is the interference for subcarrier i, n_i is the noise associated with subcarrier i, and y_i is the observation for subcarrier i. In the case of 512 subcarriers, i may range from 0 to 511. The I_i and n_i are not separated and may be considered one quantity. The interference/noise and channel gain H_i are not know. During pilot periods, the signal S_i representing the pilot symbols, and the observation y_i are knowns, thereby allowing determination of the channel gain H_i for the case where there is no interference or noise. Once this is known, it may be plugged back into the equation to determine the interference/noise during data periods since H_i, S_i and y_i are all known.

The interference information from processing blocks 301 and 302 are used by the subscriber to select desirable clusters. In one embodiment, using processing block 303, the subscriber orders clusters and also predicts the data rate that would be available using such clusters. The predicted data rate information may be obtained from a look up table with precalculated data rate values. Such a look up table may store the pairs of each SINR and its associated desirable transmission rate. Based on this information, the subscriber selects clusters that it desires to use based on predetermined performance criteria. Using the ordered list of clusters, the subscriber requests the desired clusters along with coding and modulation rates known to the subscriber to achieve desired data rates.

Figure 4 is one embodiment of an apparatus for the selection of clusters based on power difference. The approach uses information available during both pilot symbol periods and data traffic periods to perform energy detection. The processing of Figure 4 may be implemented in hardware, (e.g., dedicated logic, circuitry, etc.), software (such as is run on, for example, a general purpose computer system or dedicated machine), or a combination of both.

Referring to Figure 4, a subscriber includes SINR estimation processing block 401 to perform SINR estimation for each cluster in pilot periods, power calculation processing block 402 to perform power calculations for each cluster in pilot periods, and

power calculation processing block 403 to perform power calculations in data periods for each cluster. Subtractor 404 subtracts the power calculations for data periods from processing block 403 from those in pilot periods from processing block 402. The output of subtractor 404 is input to power difference ordering (and group selection) processing block 405 that performs cluster ordering and selection based on SINR and the power difference between pilot periods and data periods. Once the clusters have been selected, the subscriber requests the selected clusters and the coding/modulation rates with processing block 406.

More specifically, in one embodiment, the signal power of each cluster during the pilot periods is compared with that during the traffic periods, according to the following:

$$P_P = P_S + P_I + P_N,$$

$$P_D = \begin{cases} P_N\text{, with no signal and interference} \\ P_S + P_N\text{, with signal only} \\ P_I + P_N\text{, with interference only} \\ P_S + P_I + P_N\text{, with both signal and interference} \end{cases}$$

$$P_P - P_D = \begin{cases} P_S + P_I\text{, with no signal and interference} \\ P_I\text{, with signal only} \\ P_S\text{, with interference only} \\ 0\text{, with both signal and interference} \end{cases}$$

where P_P is the measured power corresponding to each cluster during pilot periods, P_D is the measured power during the traffic periods, P_S is the signal power, P_I is the interference power, and P_N is the noise power.

In one embodiment, the subscriber selects clusters with relatively large $P_P/(P_P - P_D)$ (e.g., larger than a threshold such as 10dB) and avoids clusters with low $P_P/(P_P - P_D)$ (e.g., lower than a threshold such as 10dB) when possible.

Alternatively, the difference may be based on the energy difference between observed samples during the pilot period and during the data traffic period for each of the subcarriers in a cluster such as the following:

$$\Delta_i = |y_i^P| - |y_i^D|$$

Thus, the subscriber sums the differences for all subcarriers.

Depending on the actual implementation, a subscriber may use the following metric, a combined function of both SINR and $P_P - P_D$, to select the clusters:

$$\beta = f(\text{SINR}, P_P / (P_P - P_D)$$

where f is a function of the two inputs. One example of f is weighted averaging (e.g., equal weights). Alternatively, a subscriber selects a cluster based on its SINR and only uses the power difference $P_P - P_D$ to distinguish clusters with similar SINR. The difference may be smaller than a threshold (e.g., 1 dB).

Both the measurement of SINR and $P_P - P_D$ can be averaged over time to reduce variance and improve accuracy. In one embodiment, a moving-average time window is used that is long enough to average out the statistical abnormity yet short enough to capture the time-varying nature of channel and interference, e.g., 1 millisecond.

Feedback Format for Downlink Cluster Allocation

In one embodiment, for the downlink, the feedback contains both the indices of selected clusters and their SINR. An exemplary format for arbitrary cluster feedback is shown in Figure 5. Referring to Figure 5, the subscriber provides a cluster index (ID) to indicate the cluster and its associated SINR value. For example, in the feedback, the subscriber provides cluster ID1 (501) and the SINR for the cluster, SINR1 (502), cluster ID2 (503) and the SINR for the cluster, SINR2 (504), and cluster ID3 (505), and the SINR for the cluster, SINR3 (506), etc. The SINR for the cluster may be created using an average of the SINRs of the subcarriers. Thus, multiple arbitrary clusters can be selected as the candidates. As discussed above, the selected clusters can also be ordered in the feedback to indicate priority. In one embodiment, the subscriber may form a priority list of clusters and sends back the SINR information in a descending order of priority.

Typically, an index to the SINR level, instead of the SINR itself is sufficient to indicate the appropriate coding/modulation for the cluster. For example, a 3-bit field can be used for SINR indexing to indicate 8 different rates of adaptive coding/modulation.

An Exemplary Base Station

The base station assigns desirable clusters to the subscriber making the request. In one embodiment, the availability of the cluster for allocation to a subscriber depends on the total traffic load on the cluster. Therefore, the base station selects the clusters not only with high SINR, but also with low traffic load.

Figure 13 is a block diagram of one embodiment of a base station. Referring to Figure 13, cluster allocation and load scheduling controller 1301 (cluster allocator) collects all the necessary information, including the downlink/uplink SINR of clusters specified for each subscriber (e.g., via SINR/rate indices signals 1313 received from OFDM transceiver 1305) and user data, queue fullness/traffic load (e.g., via user data buffer information 1311 from multi-user data buffer 1302). Using this information, controller 1301 makes the decision on cluster allocation and load scheduling for each user, and stores the decision information in a memory (not shown). Controller 1301 informs the subscribers about the decisions through control signal channels (e.g., control signal/cluster allocation 1312 via OFDM transceiver 1305). Controller 1301 updates the decisions during retraining.

In one embodiment, controller 1301 also performs admission control to user access since it knows the traffic load of the system. This may be performed by controlling user data buffers 1302 using admission control signals 1310.

The packet data of User 1 ~ N are stored in the user data buffers 1302. For downlink, with the control of controller 1301, multiplexer 1303 loads the user data to cluster data buffers (for Cluster 1 ~ M) waiting to be transmitted. For the uplink, multiplexer 1303 sends the data in the cluster buffers to the corresponding user buffers. Cluster buffer 1304 stores the signal to be transmitted through OFDM transceiver 1305 (for downlink) and the signal received from transceiver 1305. In one embodiment, each user might occupy multiple clusters and each cluster might be shared by multiple users (in a time-division-multiplexing fashion).

<u>Group-Based Cluster Allocation</u>

In another embodiment, for the downlink, the clusters are partitioned into groups. Each group can include multiple clusters. Figure 6 illustrates an exemplary partitioning. Referring to Figure 6, groups 1-4 are shown with arrows pointing to clusters that are in each group as a result of the partitioning. In one embodiment, the clusters within each group are spaced far apart over the entire bandwidth. In one embodiment, the clusters

within each group are spaced apart farther than the channel coherence bandwidth, i.e. the bandwidth within which the channel response remains roughly the same. A typical value of coherence bandwidth is 100 kHz for many cellular systems. This improves frequency diversity within each group and increases the probability that at least some of the clusters within a group can provide high SINR. The clusters may be allocated in groups. Goals of group-based cluster allocation include reducing the data bits for cluster indexing, thereby reducing the bandwidth requirements of the feedback channel (information) and control channel (information) for cluster allocation. Group-based cluster allocation may also be used to reduce inter-cell interference.

After receiving the pilot signal from the base station, a subscriber sends back the channel information on one or more cluster groups, simultaneously or sequentially. In one embodiment, only the information on some of the groups is sent back to the base station. Many criteria can be used to choose and order the groups, based on the channel information, the inter-cell interference levels, and the intra-cell traffic load on each cluster.

In one embodiment, a subscriber first selects the group with the best overall performance and then feedbacks the SINR information for the clusters in that group. The subscriber may order the groups based on their number of clusters for which the SINR is higher than a predefined threshold. By transmitting the SINR of all the clusters in the group sequentially, only the group index, instead of all the cluster indices, needs to be transmitted. Thus, the feedback for each group generally contains two types of information: the group index and the SINR value of each cluster within the group. Figure 7 illustrates an exemplary format for indicating a group-based cluster allocation. Referring to Figure 7, a group ID, ID1, is followed by the SINR values for each of the clusters in the group. This can significantly reduce the feedback overhead.

Upon receiving the feedback information from the subscriber, the cluster allocator at the base station selects multiple clusters from one or more groups, if available, and then assigns the clusters to the subscriber. This selection may be performed by an allocation in a media access control portion of the base station.

Furthermore, in a multi-cell environment, groups can have different priorities associated with different cells. In one embodiment, the subscriber's selection of a group is biased by the group priority, which means that certain subscribers have higher priorities on the usage of some groups than the other subscribers.

In one embodiment, there is no fixed association between one subscriber and one cluster group; however, in an alternative embodiment there may be such a fixed association. In an implementation having a fixed association between a subscriber and one or more cluster groups, the group index in the feedback information can be omitted, because this information is known to both subscriber and base station by default.

In another embodiment, the pilot signal sent from the base station to the subscriber also indicates the availability of each cluster, e.g., the pilot signal shows which clusters have already been allocated for other subscribers and which clusters are available for new allocations. For example, the base station can transmit a pilot sequence 1111 1111 on the subcarriers of a cluster to indicate that the cluster is available, and 1111 -1-1-1-1 to indicate the cluster is not available. At the receiver, the subscriber first distinguishes the two sequences using the signal processing methods which are well known in the art, e.g., the correlation methods, and then estimates the channel and interference level.

With the combination of this information and the channel characteristics obtained by the subscriber, the subscriber can prioritize the groups to achieve both high SINR and good load balancing.

In one embodiment, the subscriber protects the feedback information by using error correcting codes. In one embodiment, the SINR information in the feedback is first compressed using source coding techniques, e.g., differential encoding, and then encoded by the channel codes.

Figure 8 shows one embodiment of a frequency reuse pattern for an exemplary cellular set up. Each cell has hexagonal structure with six sectors using directional antennas at the base stations. Between the cells, the frequency reuse factor is one. Within each cell, the frequency reuse factor is 2 where the sectors use two frequencies alternatively. As shown in Figure 8, each shaded sector uses half of the available OFDMA clusters and each unshaded sector uses the other half of the clusters. Without loss of generality, the clusters used by the shaded sectors are referred to herein as odd clusters and those used by the unshaded sectors are referred to herein as even clusters.

Consider the downlink signaling with omni-directional antennas at the subscribers. From Figure 8, it is clear that for the downlink in the shaded sectors, Cell A interferes with Cell B, which in turn interferes with Cell C, which in turn interferes with Cell A, namely, A -> B -> C ->A. For the unshaded sectors, Cell A interferes with Cell

C, which in turn interferes with Cell B, which in turn interferes with Cell A, namely, A -> C -> B ->A.

Sector A1 receives interference from Sector C1, but its transmission interferes with Sector B1. Namely, its interference source and the victims with which it interferes are not the same. This might cause a stability problem in a distributed cluster-allocation system using interference avoidance: if a frequency cluster is assigned in Sector B1 but not in Sector C1, the cluster may be assigned in A1 because it may be seen as clean in A1. However, the assignment of this cluster A1 can cause interference problem to the existing assignment in B1.

In one embodiment, different cluster groups are assigned different priorities for use in different cells to alleviate the aforementioned problem when the traffic load is progressively added to a sector. The priority orders are jointly designed such that a cluster can be selectively assigned to avoid interference from its interference source, while reducing, and potentially minimizing, the probability of causing interference problem to existing assignments in other cells.

Using the aforementioned example, the odd clusters (used by the shaded sectors) are partitioned into 3 groups: Group 1, 2, 3. The priority orders are listed in Table 2.

Table 2: Priority ordering for the downlink of the shaded sectors.

Priority Ordering	Cell A	Cell B	Cell C
1	Group 1	Group 3	Group 2
2	Group 2	Group 1	Group 3
3	Group 3	Group 2	Group 1

Consider Sector A1. First, the clusters in Group 1 are selectively assigned. If there are still more subscribers demanding clusters, the clusters in Group 2 are selectively assigned to subscribers, depending on the measured SINR (avoiding the clusters receiving strong interference from Sector C1). Note that the newly assigned clusters from Group 2 to Sector A1 shall not cause interference problem in Sector B1, unless the load in Sector B1 is so heavy that the clusters in both Group 3 and 1 are used up and the clusters in Group 2 are also used. Table 3 shows the cluster usage when less than 2/3 of all the available clusters are used in Sector A1, B1, and C1.

Table 3: Cluster usage for the downlink of the shaded sectors with less than 2/3 of the full load.

Cluster Usage	Cell A	Cell B	Cell C
1	Group 1	Group 3	Group 2
2	Group 2	Group 1	Group 3
3			

Table 4 shows the priority orders for the unshaded sectors, which are different from those for the shaded sectors, since the interfering relationship is reversed.

Table 4: Priority ordering for the downlink of the unshaded sectors.

Priority Ordering	Cell A	Cell B	Cell C
1	Group 1	Group 2	Group 3
2	Group 2	Group 3	Group 1
3	Group 3	Group 1	Group 2

Intelligent Switching between Coherence and Diversity Clusters

In one embodiment, there are two categories of clusters: coherence clusters, containing multiple subcarriers close to each other and diversity clusters, containing multiple subcarriers with at least some of the subcarriers spread far apart over the spectrum. The closeness of the multiple subcarriers in coherence clusters is preferably within the channel coherence bandwidth, i.e. the bandwidth within which the channel response remains roughly the same, which is typically within 100 kHz for many cellular systems. On the other hand, the spread of subcarriers in diversity clusters is preferably larger than the channel coherence bandwidth, typically within 100 kHz for many cellular systems. Of course, the larger the spread, the better the diversity. Therefore, a general goal in such cases is to maximize the spread.

Figure 9 illustrates exemplary cluster formats for coherence clusters and diversity clusters for Cells A-C. Referring to Figure 9, for cells A-C, the labeling of frequencies (subcarriers) indicates whether the frequencies are part of coherence or diversity clusters. For example, those frequencies labeled 1-8 are diversity clusters and those labeled 9-16 are coherence clusters. For example, all frequencies labeled 1 in a cell are part of one diversity cluster, all frequencies labeled 2 in a cell are part of another diversity cluster, etc., while the group of frequencies labeled 9 are one coherence cluster, the group of

frequencies labeled 10 are another coherence cluster, etc. The diversity clusters can be configured differently for different cells to reduce the effect of inter-cell interference through interference averaging.

Figure 9 shows example cluster configurations for three neighboring cells. The interference from a particular cluster in one cell are distributed to many clusters in other cells, e.g., the interference from Cluster 1 in Cell A are distributed to Cluster 1, 8, 7, 6 in Cell B. This significantly reduces the interference power to any particular cluster in Cell B. Likewise, the interference to any particular cluster in one cell comes from many different clusters in other cells. Since not all cluster are strong interferers, diversity clusters, with channel coding across its subcarriers, provide interference diversity gain. Therefore, it is advantageous to assign diversity clusters to subscribers that are close (e.g., within the coherent bandwidth) to the cell boundaries and are more subject to inter-cell interference.

Since the subcarriers in a coherence cluster are consecutive or close (e.g., within the coherent bandwidth) to each other, they are likely within the coherent bandwidth of the channel fading. Therefore, the channel gain of a coherence cluster can vary significantly and cluster selection can greatly improve the performance. On the other hand, the average channel gain of a diversity cluster has less of a degree of variation due to the inherent frequency diversity among the multiple subcarriers spread over the spectrum. With channel coding across the subcarriers within the cluster, diversity clusters are more robust to cluster mis-selection (by the nature of diversification itself), while yielding possibly less gain from cluster selection. Channel coding across the subcarriers means that each codeword contains bits transmitted from multiple subcarriers, and more specifically, the difference bits between codewords (error vector) are distributed among multiple subcarriers.

More frequency diversity can be obtained through subcarrier hopping over time in which a subscriber occupies a set of subcarriers at one time slot and another different set of subcarriers at a different time slot. One coding unit (frame) contains multiple such time slots and the transmitted bits are encoded across the entire frame.

Figure 10 illustrates diversity cluster with subcarrier hopping. Referring to Figure 10, there are four diversity clusters in each of cells A and B shown, with each subcarrier in individual diversity clusters having the same label (1, 2, 3, or 4). There are four separate time slots shown and during each of the time slots, the subcarriers for each

of the diversity clusters change. For example, in cell A, subcarrier 1 is part of diversity cluster 1 during time slot 1, is part of diversity cluster 2 during time slot 2, is part of diversity cluster 3 during time slot 3, and is part of diversity cluster 4 during time slot 4. Thus, more interference diversity can be obtained through subcarrier hopping over time, with further interference diversity achieved by using different hopping patterns for different cells, as shown in Figure 10.

The manner in which the subscriber changes the subcarriers (hopping sequences) can be different for different cells in order to achieve better interference averaging through coding.

For static subscribers, such as in fixed wireless access, the channels change very little over time. Selective cluster allocation using the coherence clusters achieves good performance. On the other hand, for mobile subscribers, the channel time variance (the variance due to changes in the channel over time) can be very large. A high-gain cluster at one time can be in deep fade at another. Therefore, cluster allocation needs to be updated at a rapid rate, causing significant control overhead. In this case, diversity clusters can be used to provide extra robustness and to alleviate the overhead of frequent cluster reallocation. In one embodiment, cluster allocation is performed faster than the channel changing rate, which is often measured by the channel Doppler rate (in Hz), i.e. how many cycles the channel changes per second where the channel is completely different after one cycle. Note that selective cluster allocation can be performed on both coherence and diversity clusters.

In one embodiment, for cells containing mixed mobile and fixed subscribers, a channel/interference variation detector can be implemented at either the subscriber or the base station, or both. Using the detection results, the subscriber and the base station intelligently selects diversity clusters to mobile subscribers or fixed subscribers at cell boundaries, and coherence clusters to fixed subscribers close to the base station. The channel/interference variation detector measures the channel (SINR) variation from time to time for each cluster. For example, in one embodiment, the channel/interference detector measures the power difference between pilot symbols for each cluster and averages the difference over a moving window (e.g., 4 time slots). A large difference indicates that channel/interference changes frequently and subcarrier allocation may be not reliable. In such a case, diversity clusters are more desirable for the subscriber.

Figure 11 is a flow diagram of one embodiment of a process for intelligent selection between diversity clusters and coherence clusters depending on subscribers mobility. The process is performed by processing logic that may comprise hardware (e.g., circuitry, dedicated logic, etc.), software (such as that which runs on, for example, a general purpose computer system or dedicated machine), or a combination of both.

Referring to Figure 11, processing logic in the base station performs channel/interference variation detection (processing block 1101). Processing logic then tests whether the results of the channel/interference variation detection indicate that the user is mobile or in a fixed position close to the edge of the cell (processing block 1102). If the user is not mobile or is not in a fixed position close to the edge of the cell, processing transitions to processing block 1103 where processing logic in the base station selects coherence clusters; otherwise, processing transitions to processing block 1104 in which processing logic in the base station selects diversity clusters.

The selection can be updated and intelligently switched during retraining.

The ratio/allocation of the numbers of coherence and diversity clusters in a cell depends on the ratio of the population of mobile and fixed subscribers. When the population changes as the system evolves, the allocation of coherence and diversity clusters can be reconfigured to accommodate the new system needs. Figure 12 illustrates a reconfiguration of cluster classification which can support more mobile subscribers than that in Figure 9.

Whereas many alterations and modifications of the present invention will no doubt become apparent to a person of ordinary skill in the art after having read the foregoing description, it is to be understood that any particular embodiment shown and described by way of illustration is in no way intended to be considered limiting. Therefore, references to details of various embodiments are not intended to limit the scope of the claims which in themselves recite only those features regarded as essential to the invention.

CLAIMS

We claim:

1. A method for subcarrier selection for a system employing orthogonal frequency division multiple access (OFDMA) comprising:

a subscriber measuring channel and interference information for a plurality of subcarriers based on pilot symbols received from a base station;

the subscriber selecting a set of candidate subcarriers;

the subscriber providing feedback information on the set of candidate subcarriers to the base station; and

the subscriber receiving an indication of subcarriers of the set of subcarriers selected by the base station for use by the subscriber.

2. The method defined in Claim 1 further comprising the subscriber continuously monitoring reception of the pilot symbols known to the base station and measuring signal-plus-interference-to-noise ratio (SINR) of each cluster of subcarriers.

3. The method defined in Claim 2 further comprising the subscriber measuring inter-cell interference, wherein the subscriber selects candidate subcarriers based on the inter-cell interference.

4. The method defined in Claim 3 further comprising the base station selecting subcarriers for the subscriber based on inter-cell interference avoidance.

5. The method defined in Claim 2 further comprising the subscriber measuring intra-cell traffic, wherein the subscriber selects candidate subcarriers based on the intra-cell traffic load balancing.

6. The method defined in Claim 5 further comprising the base station selecting the subcarriers in order to balance intra-cell traffic load on each cluster.

7. The method defined in Claim 1 further comprising the subscriber submitting new feedback information after being allocated the set of subscribers to be allocated a new set of subcarriers and thereafter the subscriber receiving another indication of the new set of subcarriers.

8. The method defined in Claim 1 further comprising the subscriber using information from pilot symbol periods and data periods to measure channel and interference information.

9. The method defined in Claim 8 wherein the subscriber selects candidate subcarriers based on the SINR of a cluster of subcarriers and a difference between measured power corresponding to each cluster during pilot periods and measured power during data periods.

10. The method defined in Claim 9 further comprising the subscriber using the power difference to distinguish, during selection, clusters of subcarriers having substantially similar SINRs.

11. The method defined in Claim 8 further comprising the subscriber using information from pilot symbol periods and data traffic periods to analyze presence of intra-cell traffic load and inter-cell interference.

12. The method defined in Claim 1 wherein the pilot symbols occupy an entire OFDM frequency bandwidth.

13. The method defined in Claim 12 wherein at least one other pilot symbol from a different cell transmitted at the same time as the pilot symbols received from the base station collide with each other.

14. The method defined in Claim 1 further comprising the base station selecting the subcarriers from the set of candidate subcarriers based on additional information available to the base station.

15. The method defined in Claim 14 wherein the additional information comprises traffic load information on each cluster of subcarriers.

16. The method defined in Claim 15 wherein the traffic load information is provided by a data buffer in the base station.

17. The method defined in Claim 1 wherein the indication of subcarriers is received via a downlink control channel.

18. The method defined in Claim 1 wherein the plurality of subcarriers comprises all subcarriers allocable by a base station.

19. The method defined in Claim 1 wherein providing feedback information comprises arbitrarily ordering the set of candidate of subcarriers as clusters of subcarriers.

20. The method defined in Claim 19 wherein arbitrarily order candidate clusters comprise clusters in an order with most desirable candidate clusters being listed first.

21. The method defined in Claim 19 wherein the feedback information includes an index indication of a candidate cluster with its SINR value.

22. The method defined in Claim 21 wherein each index is indicative of a coding and modulation rate.

23. The method defined in Claim 1 wherein providing feedback information comprises sequentially ordering candidate clusters.

24. The method defined in Claim 1 further comprising the subscriber sending an indication of coding and modulation rates that the subscriber desires to employ for each cluster.

25. The method defined in Claim 24 wherein the indication of coding and modulation rates comprises an SINR index indicative of a coding and modulation rate.

26. The method defined in Claim 1 further comprising:

the base station allocating a first portion of the subcarriers to establish a data link between the base station and the subscriber; and then

the base station allocating a second portion of the subcarriers to the subscriber to increase communication bandwidth.

27. The method defined in Claim 26 wherein the base station allocates the second portion after allocating each subscriber in the cell subcarriers to establish a data link between the base station and said each subscriber.

28. The method defined in Claim 26 wherein, due to subscriber priority, the base station allocates the second portion before allocating each subscriber in the cell subcarriers to establish their data link to the base station.

29. An apparatus comprising:

a plurality of subscribers in a first cell to generate feedback information indicating clusters of subcarriers desired for use by the plurality of subscribers; and

a first base station in the first cell, the first base station performing subcarrier allocation for OFDMA to allocate OFDMA subcarriers in clusters to the plurality of subscribers based on inter-cell interference avoidance and intra-cell traffic load balancing in response to the feedback information.

30. An apparatus comprising:

a plurality of subscribers in a first cell to generate feedback information indicating clusters of subcarriers desired for use by the plurality of subscribers; and

a first base station in the first cell, the first base station to allocate OFDMA subcarriers in clusters to the plurality of subscribers;

each of a plurality of subscribers to measure channel and interference information for the plurality of subcarriers based on pilot symbols received from the first base station and at least one of the plurality of subscribers to select a set of candidate subcarriers from the plurality of subcarriers, and the one subscriber to provide feedback information on the set of candidate subcarriers to the base station and to receive an indication of subcarriers from the set of subcarriers selected by the first base station for use by the one subscriber.

31. The apparatus defined in Claim 30 wherein each of the plurality of subscribers continuously monitors reception of the pilot symbols known to the base station and the plurality of subscribers and measures signal-plus-interference-to-noise ratio (SINR) of each cluster of subcarriers.

32. The apparatus defined in Claim 31 wherein each of the plurality of subscribers measures inter-cell interference, wherein the at least one subscriber selects candidate subcarriers based on the inter-cell interference.

33. The apparatus defined in Claim 32 wherein the base station selects subcarriers for the one subscriber based on inter-cell interference avoidance.

34. The apparatus defined in Claim 31 wherein each of the plurality of subscribers measures intra-cell traffic, wherein the at least one subscriber selects candidate subcarriers based on the intra-cell traffic load balancing.

35. The apparatus defined in Claim 34 wherein the base station selects subcarriers in order to balance intra-cell traffic load on each cluster of subcarriers.

36. The apparatus defined in Claim 30 wherein the subscriber submits new feedback information after being allocated the set of subscribers to receive a new set of subcarriers and thereafter receives another indication of the new set of subcarriers.

37. The apparatus defined in Claim 30 wherein the at least one subscriber uses information from pilot symbol periods and data periods to measure channel and interference information.

38. The apparatus defined in Claim 30 wherein the at least one subscriber selects candidate subcarriers based on SINR of the cluster and a difference between

measured power corresponding to each cluster during pilot periods and measured power during data periods.

39. The apparatus defined in Claim 38 wherein the one subscriber distinguishes, during selection, cluster of subcarriers having substantially similar SINRs based on the power difference.

40. The apparatus defined in Claim 38 wherein the at least one subscriber uses information from pilot symbol periods and data traffic periods to analyze presence of intra-cell traffic load and inter-cell interference.

41. The apparatus defined in Claim 38 wherein the pilot symbols occupy an entire OFDM frequency bandwidth.

42. The apparatus defined in Claim 41 wherein at least one other pilot symbol from a different cell transmitted at the same time as the pilot symbols received from the base station collide with each other.

43. The apparatus defined in Claim 30 wherein the base station selects the subcarriers from the set of candidate subcarriers based on additional information available to the base station.

44. The apparatus defined in Claim 43 wherein the additional information comprises traffic load information on each cluster of subcarriers.

45. The apparatus defined in Claim 44 wherein the traffic load information is provided by a data buffer in the base station.

46. The apparatus defined in Claim 30 wherein the indication of subcarriers is received via a downlink control channel between the base station and the at least one subscriber.

47. The apparatus defined in Claim 30 wherein the plurality of subcarriers comprises all subcarriers allocable by a base station.

48. The apparatus defined in Claim 30 wherein the plurality of subscribers provide feedback information that comprises an arbitrarily ordered set of candidate subcarriers as clusters of subcarriers.

49. The apparatus defined in Claim 48 wherein arbitrarily order candidate clusters comprise clusters in an order with most desirable candidate clusters being listed first.

50. The apparatus defined in Claim 48 wherein the feedback information includes an index indication of a candidate cluster with it SINR value.

51. The apparatus defined in Claim 50 wherein each index is indicative of a coding and modulation rate.

52. The apparatus defined in Claim 30 wherein providing feedback information comprises sequentially ordering candidate clusters.

53. The apparatus defined in Claim 30 wherein the one subscriber sends an indication of coding and modulation rates that the one subscriber desires to employ.

54. The apparatus defined in Claim 53 wherein the indication of coding and modulation rates comprises an SINR index indicative of a coding and modulation rate.

55. The apparatus defined in Claim 30 wherein the base station allocates a first portion of the subcarriers to establish a data link between the base station and the subscriber; and then allocates a second portion of the subcarriers to the subscriber to increase communication bandwidth.

56. The apparatus defined in Claim 55 wherein the base station allocates the second portion after allocating each subscriber in the cell subcarriers to establish a data link between the base station and said each subscriber.

57. The apparatus defined in Claim 55 wherein, due to subscriber priority, the base station allocates the second portion before allocating each subscriber in the cell subcarriers to establish their data link to the base station.

58. A method comprising:

the base station allocating a first portion of the subcarriers to establish a data link between the base station and the subscriber; and then

the base station allocating a second portion of the subcarriers to the subscriber to increase communication bandwidth.

59. The method defined in Claim 57 wherein the base station allocates the second portion after allocating each subscriber in the cell subcarriers to establish a data link between the base station and said each subscriber.

60. A base station comprising:

means for allocating a first portion of the subcarriers to establish a data link between the base station and the subscriber; and

means for allocating a second portion of the subcarriers to the subscriber to increase communication bandwidth.

61. The apparatus defined in Claim 60 wherein the base station allocates the second portion after allocating each subscriber in the cell subcarriers to establish a data link between the base station and said each subscriber.

62. An apparatus comprising:

a plurality of subscribers in a cell; and

a base station in the cell, the base station to perform subcarrier allocation for OFDMA to allocate OFDMA subcarriers in clusters to the plurality of subscribers based on inter-cell interference avoidance and intra-cell traffic load balancing.

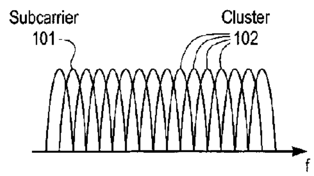

Subcarrier
101
Cluster
102
f

FIG. 1A

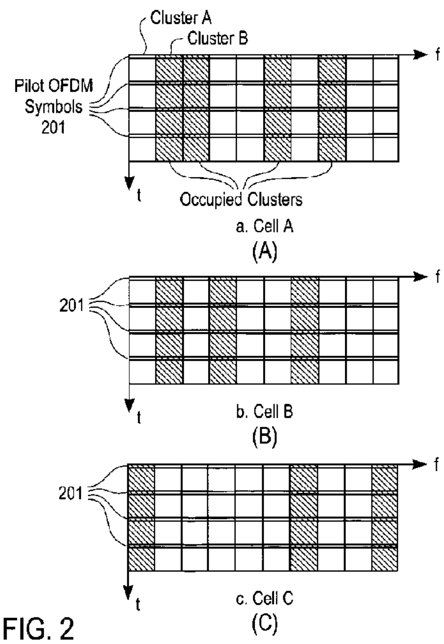

Cluster A
Cluster B
f
Pilot OFDM
Symbols
201
t
Occupied Clusters
a. Cell A
(A)
f
201
t
b. Cell B
(B)
f
201
t
c. Cell C
(C)

FIG. 2

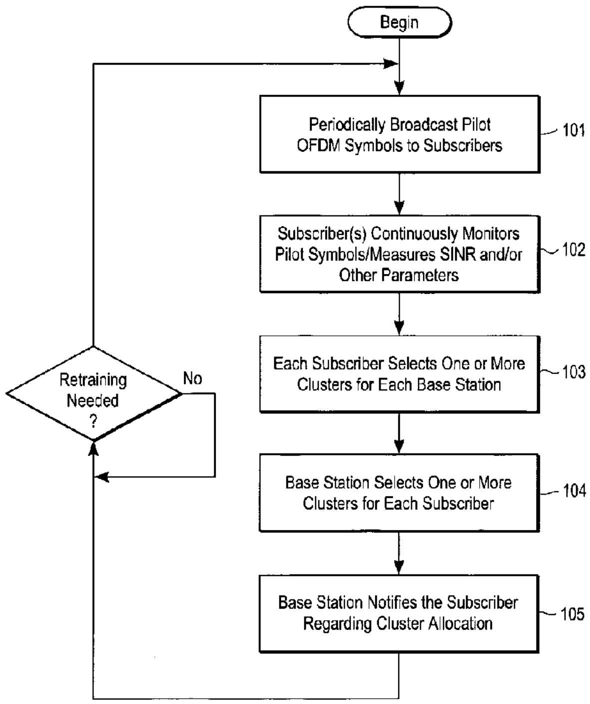

Begin
Periodically Broadcast Pilot OFDM Symbols to Subscribers
101
Subscriber(s) Continuously Monitors Pilot Symbols/Measures SINR and/or Other Parameters
102
Each Subscriber Selects One or More Clusters for Each Base Station
103
Base Station Selects One or More Clusters for Each Subscriber
104
Base Station Notifies the Subscriber Regarding Cluster Allocation
105
Retraining Needed ?
No

FIG. 1B

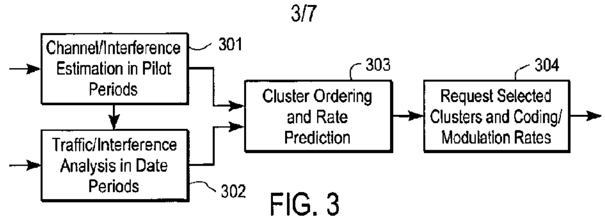


FIG. 3

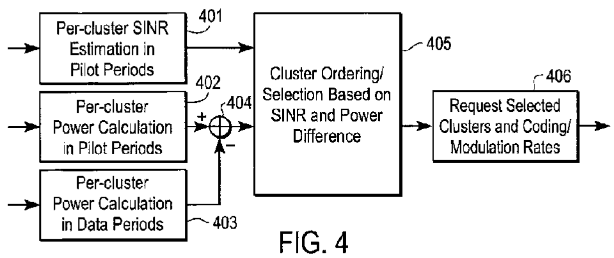


FIG. 4

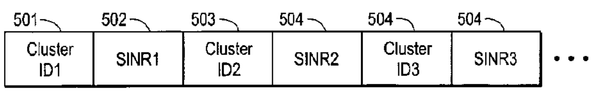


FIG. 5

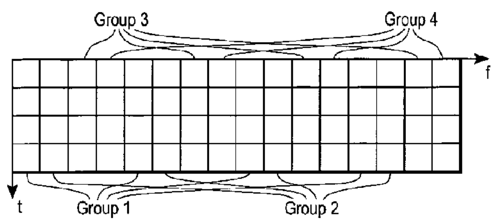


FIG. 6

Group ID1	SINR1	SINR2	SINR3	Group ID2	SINR1	SINR2	SINR3	• • •

FIG. 7

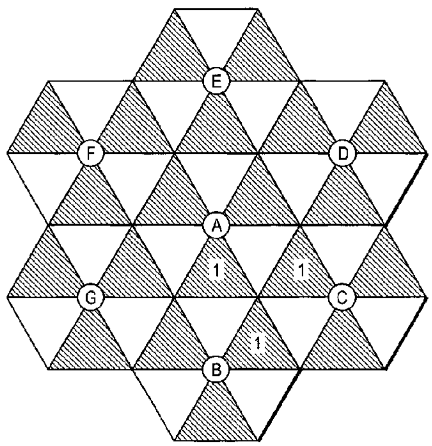


FIG. 8

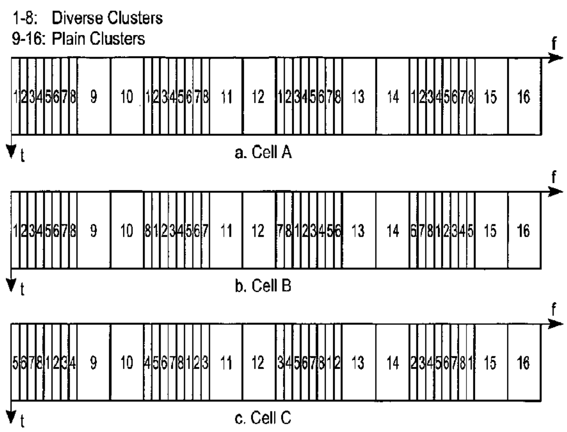

1-8: Diverse Clusters
9-16: Plain Clusters
f
t
a. Cell A
b. Cell B
c. Cell C

FIG. 9

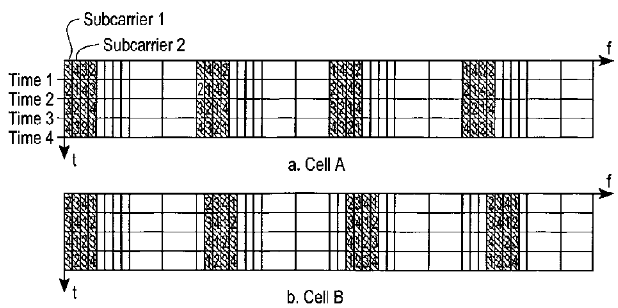
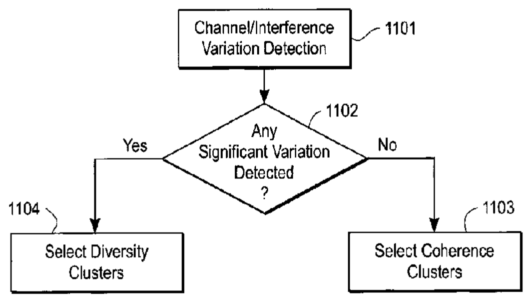
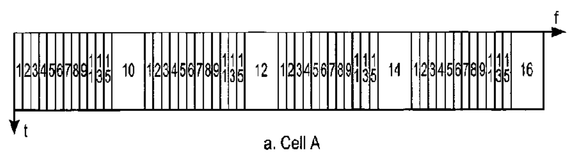

Subcarrier 1
Subcarrier 2
Time 1
Time 2
Time 3
Time 4
f
t
a. Cell A
b. Cell B

FIG. 10



Channel/Interference Variation Detection
1101
1102
Any Significant Variation Detected ?
Yes
No
1104
1103
Select Diversity Clusters
Select Coherence Clusters

FIG. 11



f
t
10
12
14
16
a. Cell A

FIG. 12

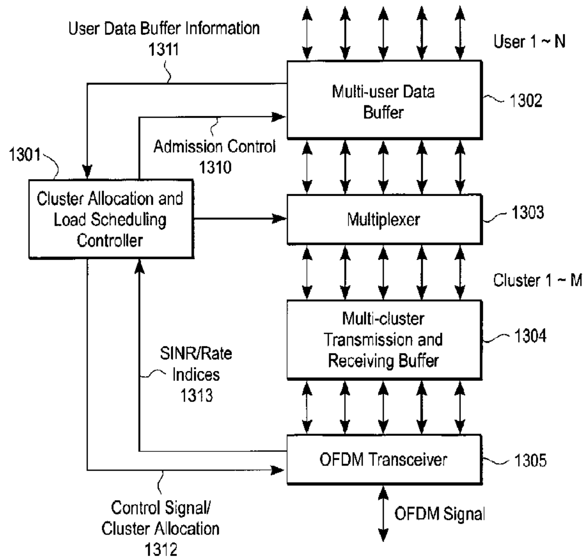

User Data Buffer Information
1311
User 1 ~ N
Multi-user Data Buffer
1302
Admission Control
1310
1301
Cluster Allocation and Load Scheduling Controller
Multiplexer
1303
Cluster 1 ~ M
Multi-cluster Transmission and Receiving Buffer
1304
SINR/Rate Indices
1313
OFDM Transceiver
1305
Control Signal/ Cluster Allocation
1312
OFDM Signal

FIG. 13

【国際調査報告】

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 01/48421

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H04L27/26 H04Q7/36 H04Q7/38 H04L5/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H04L H04Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 726 978 A (FRODIGH CARL MAGNUS ET AL) 10 March 1998 (1998-03-10)	1-7,14, 15, 17-19, 29-36, 43,44, 46,47
	column 4, line 25 -column 5, line 25 column 7, line 39 - line 50 column 8, line 64 -column 9, line 16 column 12, line 57 - line 64 column 13, line 5 - line 22 figures 2,3C,4A,4B,5,6A	
X		62

	-/--	

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
24 July 2002	12.08.02

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Palacián Lisa, M

Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

I onal Application No
PCT/US 01/48421

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 914 933 A (CIMINI LEONARD JOSEPH ET AL) 22 June 1999 (1999-06-22) column 2, line 1 - line 20 column 3, line 26 -column 4, line 50 column 9, line 1 - line 12	1,2,7,8, 17-19, 29-31, 46,47
X	US 5 479 447 A (CIOFFI JOHN M ET AL) 26 December 1995 (1995-12-26) column 3, line 42 - line 56 column 5, line 42 -column 6, line 15 column 12, line 25 - line 44	1-7, 14-19, 29-36, 43-47
X	EP 0 869 647 A (LUCENT TECHNOLOGIES INC) 7 October 1998 (1998-10-07) page 2, line 26 - line 55 page 3, line 15 - line 40 page 5, line 24 - line 40 page 6, line 9 - line 54 page 7, line 30 - line 37	1,2, 17-19, 26, 29-31, 46,47,55
X		58-61
A	US 5 708 973 A (RITTER GERHARD) 13 January 1998 (1998-01-13) the whole document	1-57
A	WONG C Y ET AL: "MULTIUSER OFDM WITH ADAPTIVE SUBCARRIER, BIT, AND POWER ALLOCATION" , IEEE JOURNAL ON SELECTED AREAS IN COMMUNICATIONS, IEEE INC. NEW YORK, US, VOL. 17, NR. 10, PAGE(S) 1747-1758 XP000854075 ISSN: 0733-8716 Sections I and II abstract	1-57
A	US 6 131 016 A (SOLLENBERGER NELSON RAY ET AL) 10 October 2000 (2000-10-10) abstract column 1, line 40 -column 2, line 12 column 2, line 66 -column 3, line 22	1-57
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Form PCT/ISA/210 (continuation of second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 01/48421

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
X	GRUENHEID R ET AL: "ADAPTIVE MODULATION AND MULTIPLE ACCESS FOR THE OFDM TRANSMISSION TECHNIQUE" , WIRELESS PERSONAL COMMUNICATIONS, KLUWER ACADEMIC PUBLISHERS, NL, VOL. 13, NR. 1/2, PAGE(S) 5-13 XP000894156 ISSN: 0929-6212 abstract Section 2 Section 5.2	58-61
X	KINUGAWA Y ET AL: "FREQUENCY AND TIME DIVISION MULTIPLE ACCESS WITH DEMAND-ASSIGNMENT USING MULTICARRIER MODULATION FOR INDOOR WIRELESS COMMUNICATIONS SYSTEMS" , IEICE TRANSACTIONS ON COMMUNICATIONS, INSTITUTE OF ELECTRONICS INFORMATION AND COMM. ENG. TOKYO, JP, VOL. E77-B, NR. 3, PAGE(S) 396-402 XP000451014 ISSN: 0916 8516 abstract Section 3	58-61
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X	EP 0 929 202 A (LUCENT TECHNOLOGIES INC) 14 July 1999 (1999-07-14) the whole document	62
X	DE 198 00 953 C (SIEMENS AG) 29 July 1999 (1999-07-29) column 1, line 55 -column 3, line 20	62
X	WO 98 30047 A (OTTERSTEN BJORN E ;ARRAYCOMM INC (US); YUN LOUIS C (US)) 9 July 1998 (1998-07-09) page 1, line 9 - line 14 page 6, line 26 -page 10, line 15	62

Form PCT/ISA/210 (continuation of second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 01/48421

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☒ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest.

☒ No protest accompanied the payment of additional search fees.

Form PCT/ISA/210 (continuation of first sheet (1)) (July 1998)

International Application No. PCT/US 01 /18421

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. Claims: 1-57

   Method and apparatus for subcarrier selection wherein a base station allocates channels to subscribers based on feedback information from the subscriber.

2. Claims: 58-61

   A method and a base station for allocating a first portion of the subcarriers to establish a data link with the subscriber and for allocating a second portion of the subcarriers to increase the bandwidth.

3. Claim : 62

   An apparatus wherein a base station allocates OFDM subcarriers to a plurality of users based on inter-cell interference avoidance and intra-cell traffic load balancing.

INTERNATIONAL SEARCH REPORT
Information on patent family members

onal Application No
PCT/US 01/48421

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
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(81)指定国 AP(GH,GM,KE,LS,MW,MZ,SD,SL,SZ,TZ,UG,ZM,ZW),EA(AM,AZ,BY,KG,KZ,MD,RU,TJ,TM),EP(AT,BE,CH,CY,DE,DK,ES,FI,FR,GB,GR,IE,IT,LU,MC,NL,PT,SE,TR),OA(BF,BJ,CF,CG,CI,CM,GA,GN,GQ,GW,ML,MR,NE,SN,TD,TG),AE,AG,AL,AM,AT,AU,AZ,BA,BB,BG,BR,BY,BZ,CA,CH,CN,CO,CR,CU,CZ,DE,DK,DM,DZ,EC,EE,ES,FI,GB,GD,GE,GH,GM,HR,HU,ID,IL,IN,IS,JP,KE,KG,KP,KR,KZ,LC,LK,LR,LS,LT,LU,LV,MA,MD,MG,MK,MN,MW,MX,MZ,NO,NZ,OM,PH,PL,PT,RO,RU,SD,SE,SG,SI,SK,SL,TJ,TM,TN,TR,TT,TZ,UA,UG,UZ,VN,YU,ZA,ZM,ZW

（特許庁注：以下のものは登録商標）
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Ｆターム(参考) 5K022 DD01 DD13 DD19 DD21 DD31
5K067 AA03 DD34 DD44 DD45 EE02 EE10 FF02 FF16 FF23 HH23
JJ11 JJ17 LL01 LL05